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Project No. 95-1590

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TRANSMITTAL
BUCKEYE LAKE DAM STABILITY STUDY
BUCKEYE LAKE STATE PARK
FAIRFIELD, LICKING, AND PERRY COUNTIES, OHIO
DNR 736 730-96-034

Dear Mr. Harsanye:

Paul C. Rizzo Associates, Inc. respectfully submits the Buckeye Lake Dam Stability Study (Study), DNR 736 730-96-034 for the Buckeye Lake Dam located in the Buckeye Lake State Park, Fairfield, Licking, and Perry Counties, Ohio. In accordance with Section B, Design Service of our Contract, ten copies of the Study are enclosed for your distribution and use.

Paul C. Rizzo Associates appreciates this opportunity to work with the Ohio Department of Natural Resources (ODNR) Division of Engineering on this project. We look forward to our continuing our association with the ODNR. If you have any questions or require additional information, please do not hesitate to contact us.

Very truly yours,
Paul C. Rizzo Associates

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President

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Project Manager

PCR/RAI/and/mfs
Enclosures

REPORT

BUCKEYE LAKE DAM STABILITY STUDY
BUCKEYE LAKE STATE PARK
FAIRFIELD, LICKING, AND PERRY COUNTIES, OHIO
DNR 736 730-96-034

PROJECT NO. 95-1590
MAY 1997

PREPARED FOR:
OHIO DEPARTMENT OF NATURAL RESOURCES
COLUMBUS, OHIO

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1.0 INTRODUCTION

Buckeye Lake is a manmade recreation lake located in Licking, Fairfield, and Perry Counties, Ohio. The 4.2 mile long Dam impounding the Lake, reportedly constructed between 1825 and 1832, has a maximum structural height of 15 feet with a crest at approximately El 895 feet mean sea level (msl). A sheetpile and/or masonry wall extends along the upstream face of the Dam and, in some reaches of the Dam, the shoreline sheet-piling was constructed against the upstream face of the old masonry Dam.

The Lake surface area is approximately 2,700 acres at normal pool. A combination drop spillway and gated outlet works is located near the northeast corner of the Lake. In addition, a U-shaped concrete gravity weir structure near Sellers Point with a crest length of 460 feet at El 892.25 feet was constructed in 1992 for normal and flood discharge.

Emergency spillway

The Dam is considered a Class I Dam by the Ohio Department of Natural Resources (ODNR) based on the size of the Lake and the probability of loss of life due to failure of the Dam. This Classification requires the Lake and Dam to accommodate a Probable Maximum Flood (PMF). The current spillway system is capable of passing a flood equivalent to 50 percent of the PMF. Consequently, a portion of the full PMF must be taken in storage in the Lake. Therefore, the crest of the Dam is to be raised to El 896.5 as part of a Phase III Remediation Plan.

The ODNR has determined that it will be necessary to maintain a temporary water surface at El 896.5 feet during and subsequent to the PMF as compared to the normal Lake level at approximately El 891.75 feet. The change in crest level from El 895.0 to El 896.5 and the PMF Lake level has prompted an investigation of the stability of the Dam.

The primary objectives of this investigation by Paul C. Rizzo Associates (PCRA) are to:

- Conduct an independent stability investigation of Buckeye Lake Dam;
- Review and address the differences in the previous stability analyses conducted by Dodson-Lindblom Associates (DLA, 1987) and W.S. Gardner and Associates (WSGA, 1995); and
- Provide a professional opinion regarding the impact of the proposed Phase III Remediation Plan on the stability of the Dam.

The results of this study are an assessment of the pre-(Before) and post-remediation (After) stability of the Dam under normal and surcharge pool (PMF) loading conditions.

By way of commentary, it should be noted that the Dam has been in place for over 165 years and, generally speaking, the performance has to be rated excellent. While seepage has been noted at some locations, piping failures have not occurred. Later in the text, we discuss the potential for piping failures. The stability of the Dam in its current state is clear as no stability failures of significant magnitude have occurred since an incident in 1832 associated with initial filling. Even this event was probably not a stability failure.

Further to this point, it is our view that the Dam has been "abused" from the perspective that the downstream toe has been excavated and replaced with house foundations and large trees have been permitted to grow on the crest and on the downstream slope. Furthermore, the life of the Dam is such that it is well beyond any condition that might be construed as significantly affecting pore pressures such as an end-of-construction case or initial filling case. Hence, the issue is whether adding a few feet of fill to raise the level of the embankment crest, combined with a postulated Probable Maximum Flood level, will impact the stability of the Dam or increase the potential for a catastrophic piping failure.

2.0 FIELD INVESTIGATIONS

A geotechnical field investigation was conducted by our firm to supplement work already accomplished by DLA. The field efforts involved additional characterization of the soils comprising the Dam embankment and underlying foundation, collection of representative soil samples for determination of classification, strength, and permeability in the laboratory, a determination of the phreatic surface (water level in saturated soils) through the Dam, and identification of any observable seepage through the Dam. A total of 21 Borings for soil sampling and Piezometer installation were advanced at five cross-section locations. The 4.2 mile long Dam was also inspected for observable seepage. Details of these activities are presented below.

2.1 SELECTIONS OF DAM CROSS-SECTION LOCATIONS

The stability analysis discussed herein considered six cross sections through the Dam at locations identified on Figure 2-1. These include a section analyzed by DLA, STA 63+61.5 (Cross Section 2) and five others (Sections 1A through 5A) developed from the field investigation associated with our effort. Detailed computerized stability analyses have been performed at DLA's "worst" cross section (Cross Section 2) and all five of our cross sections. The "worst" section from the DLA work is that associated with their lowest factor of safety against stability failure. It is noted that the five new cross-sections, coupled with the four cross-sections, originally analyzed by DLA for a total of nine cross-sections provide a highly representative view of the condition of the Dam.

The five new cross-section locations studied in our field investigation were selected on the basis of the following:

- The results of a field reconnaissance to investigate observable seepage from the Dam;
- Seepage locations reported to ODNR by residents living along the Dam;
- Data gaps between sections previously investigated by DLA; and
- Drilling rig access.

ODNR maintains a log of seepage from the Dam reported to the Buckeye Lake State Park office. This log was reviewed and considered during selection of the five cross-section locations.

Following review of ODNR's reported seepage log and an evaluation of potential drill rig access based on surface slopes and the locations of existing structures, nine preliminary cross sections were selected at positions to fill existing data gaps along the Dam. A field reconnaissance was completed on May 1, 1996 to catalog observable seepage along the Dam at normal pool conditions and to select the final five cross-section locations. The Dam was inspected beginning at the west end by walking the entire length to the north, then walking back to the west end. No obvious seepage was observed during this reconnaissance. According to Mr. Ed Frank, Buckeye Lake State Park Manager, there had been no recent reports of seepage by local residents at the time of the field reconnaissance.

The results of this field reconnaissance, coupled with the age of the Dam and the laboratory classification of the soils comprising the Embankment Fill, indicate that while there may be occasional zones of localized seepage, there is no evidence to indicate that raising the crest a few feet or raising the Lake level to temporarily store a PMF will lead to a catastrophic piping failure.

Drawings presenting selected cross-section locations, including proposed Boring locations, were submitted to ODNR for the five primary and four alternate sections. Three of the five primary sections are located on state-owned property. ODNR's Division of Real Estate and Land Management contacted home owners affected by the other two sections and obtained the necessary right-of-way waivers for drill rig access. Waivers were finalized in early July 1996 and drilling began on July 22, 1996.

2.2 DRILLING AND SOIL SAMPLING PROCEDURES

CTL Engineering, Inc. (CTL), Paul C. Rizzo Associates' selected drilling subcontractor, mobilized a small, track-mounted Simco drill rig to advance 21 Borings at five cross-section locations along the Dam. Borings were advanced using wash rotary drilling in conjunction with continuous split-barrel sampling in accordance with procedures prescribed in ASTM D-1586. Specifically, a 3-7/8 inch diameter tri-cone roller bit was used with water as the circulating fluid to advance the Boring. The wash-rotary method was used to minimize the potential for smearing the soils along the Boring walls, which, otherwise, could effect the response of Piezometers installed to characterize the phreatic surface through the Dam. Wash rotary drilling with water only was not successful at five Boring locations, B2A-1A, B2A-1B, B3A-1B, B3A-2A and B3A-2B, due to caving in the open Boring. In order to assure representative samples, 4-1/4 inch inside diameter (I.D.) hollow-stem augers were used for Boring advancement in conjunction with split-barrel sampling.

The split-barrel sampler was driven 24 inches with a 140-pound hammer dropped from a height of 30 inches. Split-barrel and undisturbed Shelby Tube samples collected for laboratory analysis are identified in Table 2-1. An experienced geologist from Paul C. Rizzo Associates logged all soil samples and prepared samples for shipment to the laboratory. Following boring and sampling to target depth, Piezometers were installed in all of the 21 Borings as described in Section 2.4. Completed Boring Logs and Piezometer Logs are presented in Appendix A.

2.3 GEOTECHNICAL LABORATORY ANALYSES

Disturbed (split-barrel) soil samples were forwarded to the laboratory for the analyses listed below:

- Atterberg limits;
- Moisture content;
- Sieve analysis;
- Hydrometer; and
- ASTM Classification.

A summary of disturbed soil sample laboratory results is presented in Table 2-2 and the completed geotechnical laboratory results are included in Appendix B.

Nine undisturbed (Shelby Tube) soil samples were collected for laboratory analyses. Four samples were submitted for laboratory testing, and the other five have been reserved for additional testing, if required. The following tests were conducted on undisturbed samples:

- Three point CU triaxial test with pore pressure measurements;
- Falling head permeability; and
- Unit weight with moisture content.

Triaxial tests were carried out to strain levels of approximately 20 percent. Undisturbed soil sample permeability results are presented in Table 2-3 and the complete geotechnical laboratory results are included in Appendix B.

2.4 PIEZOMETER INSTALLATION

Sealed Piezometers were installed in all 21 Borings drilled for this investigation at locations presented on Figures 2-2 through 2-11. Typically, Piezometers were installed on the upstream and downstream margins of the Dam crest and just above the toe of the downstream slope. At the upstream margin of the Dam crest, shallow and deep nested Piezometers were installed. Single Piezometers were installed at the other locations.

Piezometers were constructed using 1-foot long Casagrande-type, composite porous-stone and slotted polyvinyl chloride (PVC) screens. The riser pipe is 1.0-inch I.D. PVC. The screen and riser pipe are flush threaded with O-ring seals at each joint. Two stainless-steel centralizers were used to center the Piezometer in the Boring. At those locations where the Piezometer tip is positioned above the Boring bottom, granular bentonite chips were used to backfill the lower portion of the Boring.

The filter pack sand consists of coarse sand, Best Sand Grade 430, placed to a level approximately one foot above the top of the screen. A 2 foot layer of fine sand, Global No. 7, was placed above the coarse sand and is overlain by a 2 foot layer of bentonite pellets used to seal the screen. Following hydration of the bentonite seal, the Borings were tremie grouted to the surface with a cement/bentonite mixture.

Riser pipes extend to the ground surface and are protected by a 3-foot long by 4-inch diameter flush mounted locking steel casing. The protective casing was set securely into the cement/bentonite grout following installation of the Piezometer. Concrete pads, 18-inches by 18- inches by 3- inches thick, were constructed around the flush mounted locking steel casings. A PVC cap seals the one inch riser pipe.

Following installation of each Piezometer, the investigation area was returned to its original condition. Excess Boring cuttings were spread evenly over the surrounding ground surface and used as fill material for wheel ruts. Additional topsoil was also brought to the sites. Disturbed ground was then re-seeded with grass and covered with a protective layer of straw.

Water levels in the Piezometers were recorded on six dates from August to October 1996. Table 2-4 presents Piezometer water level information. Several of the installed Piezometers have been dry. As a test to determine if the screens are clogged, the dry Piezometers were filled with water and then checked approximately ten days later. All of the Piezometers which were filled with water were dry when checked again, indicating that screen clogging has not occurred. Furthermore, all of the Piezometers indicated on Table 2-4 have fluctuated at one time or another during the monitoring period, indicating that they are functioning as intended.

3.0 GENERALIZED SUBSURFACE CONDITIONS

3.1 Subsurface Characteristics at Cross Sections

To characterize the Dam Embankment Fill and the Dam Foundation Till, samples were collected from Borings at continuous two foot intervals at each cross section. An experienced geologist described each sample in the field and recorded his observations on Boring Logs presented in Appendix A. Information recorded on the logs includes:

- Sample depth;
- Grain size;
- Density or consistency (Standard Penetration Test blow counts and hand penetrometer);
- Moisture content;
- Observed soil structure; and
- Field determined Unified Soil Classification System (USCS) classification.

Fill soils used for the Dam Embankment Fill were distinguished from natural Dam Foundation Till as indicated on Boring Logs (Appendix A) and on cross sections (Figures 2-3, 2-5, 2-7 ,2-9, and 2-11).

DLA described the soils comprising the foundation beneath the Dam as follows:

> "Generalized geologic bulletins report the Dam site to lie on a post-glacial swamp. The underlying soils consist of lacustrine type deposits, silt and clay commonly laminated and interbedded with sand and sand and gravel layers. These deposits in turn overlie glacial till."

Our results, being somewhat more detailed, indicate that the post-glacial swamp deposits are of limited or intermittent areal extent, found at only two of the five cross sections (Sections 1A and 3A). Glacial till (generally described by Paul C. Rizzo Associates as silty clay, trace fine sand and rock fragments) appears to comprise the original ground surface (Foundation Till) beneath most of the Dam with only limited zones of consolidated organic silty clay.

In the upper elevations, the till is mottled and blocky to subblocky, while in the lower elevations, the till is occasionally moderately to weakly laminated, but not blocky, and contains more silt and fine sand, but less angular rock fragments. The gray to dark gray color of the lower till is the result of an oxygen deficient reducing environment, not significant organic content.

Distinguishing the Dam Embankment Fill from the Dam Foundation Till is occasionally complicated because of the observed similarities in the soil grain-size distribution of both materials, i.e., both materials are generally fine grained and classified as CL in the laboratory. Typically, fill materials are not as dense as glacial tills. However, the soils encountered in borings are not characterized by obvious consistency contrasts. At some borings, both materials are relatively soft and in other areas the consistency of the Fill ranges from hard to soft. Additional inspection of soil samples was performed in the office to check field interpretations and to correlate the samples between sections and with laboratory test results.

Soil characteristics which were used to distinguish glacial till from Embankment Fill soils include:

- **SOIL STRUCTURE**
  Glacial tills observed at the site typically exhibit a blocky to subblocky soil structure in the upper elevations, underlain by a weakly to moderately laminated or sutured structures. The Fill material typically does not exhibit any observable soil structure.

- **PERCENTAGE OF COARSE GRAINED MATERIAL**
  In some areas, the Embankment Fill material contains slightly greater percentages of coarse sand and gravel in comparison to the Foundation Till. Small rock fragments were found in both fill and glacial till.

- **COLOR**
  Glacial till typically is mottled yellow-brown and gray in the upper elevations, underlain by an unmottled gray to dark gray till. The Embankment Fill material is brown to gray (sometimes dark gray) at some locations. However, the Embankment Fill material sometimes appears to consist of brown disturbed till with no mottling or soil structure. We also note that the grain size distribution of this material is consistent with that of the mottled, glacial till.

3.2 DISCUSSION OF LABORATORY AND FIELD CLASSIFICATION OF SOILS

During field drilling operations, our geologist typically opens the 24 inch split barrel sample and makes a determination by visual inspection of the appropriate soil classification. The geologist then takes a representative portion of the overall sample and places it into a jar, then seals and labels it. The jar samples are shipped to a laboratory where specific jars are opened for testing including grain size analysis, Atterberg Limits and moisture content. Based on the grain size analysis, supported by the Atterberg Limits, the selected jar samples are reclassified according to ASTM D-2487. Occasionally, the laboratory classification is different from the field classification, especially in the case of silts and clays where it is difficult to assess the clay content with the naked eye.

The reader will note that the field classifications of the soils on the Boring Logs often describe the Embankment Fill and the Foundation Till as clayey silt or silt, and often as ML in the USCS system. On the other hand, the laboratory test results indicate that these same materials are usually "lean clays" or CL materials. The laboratory classification prevails in all cases. This was later confirmed with the triaxial test results which indicate the cohesive nature of the soils comprising the Embankment Fill and the Foundation Till.

3.3 GENERALIZED PHREATIC SURFACE AND POTENTIOMETRIC HEAD DISTRIBUTION

Phreatic surface profiles used for the stability model are presented on Sections 1A through 5A (Figures 2-3, 2-5, 2-7, 2-9 and 2-11) prepared for this study. Static water levels from Piezometers, soil properties, stratigraphy (soil layering), and the effects of the sheetpiling and masonry walls at the site were considered for preparation of the phreatic surfaces.

In consideration of the fine grained and low permeability characteristics of most of the Embankment Fill and the Foundation Till, the best model describing ground water flow beneath the Dam for the stability analysis consists of a single undifferentiated flow zone (single layer model). Other than the masonry wall and sheetpiling, there are no other significant hydraulic contrasts impeding ground water flow beneath the Dam.

Water from the Lake flows down and around the bottom of the masonry wall and sheetpiling. This interpretation assumes that these structures are relatively impermeable. The interpreted flow path around these structures is based on the significant head loss from the Lake level to the 1A (shallow) Piezometers at Sections 1A, 3A, 4A, and 5A and by the upward vertical gradient between the 1A (shallow) and 1B (deep) nested Piezometers at Sections 1A, 3A, and 5A. Sufficient data do not exist to determine the direction of the vertical gradient at Section 4A because the 1A (shallow) Piezometer is dry at this location.

The sand layers in the Embankment Fill and Foundation Till are discontinuous at all cross-section locations. We found no evidence that would indicate that sand layers extend through the cross section of the Dam at the locations investigated.

3.4 SECTION 1A SUBSURFACE CONDITIONS

Section 1A is located on the West Bank of the Dam as shown on Figures 2-1 and 2-2. Cross Section 1A is presented on Figure 2-3 and identifies the positions of four B1A-series Borings advanced for this investigation. Embankment Fill materials along this section are up to 6.0 feet thick and consist of clayey silt to silty clay, some sand, some gravel or rock fragments, and organic matter in places. The Embankment Fill is mostly stiff to very stiff, but very soft in places.

Organic material observed from 6.0 to 8.0 feet in Borings B1A-1B and B1A-2 may represent a swampy deposit at the base of the Dam. At Boring B1A-1B the organic material consistency is very soft; however, at Boring B1A-2 the consistency is stiff to very stiff.

Glacial till consisting of gray and brown mottled silty clay, soft to very hard, is found below the Embankment Fill and organic layer. Laminations were observed in the lower elevations of the till deposits. Two relatively thin, discontinuous sand/sand and gravel layers were observed at depths of 18.0 to 20.0 feet and 10.0 to 11.5 feet at Borings B1A-1B and B1A-2, respectively.

The interpreted phreatic surface for Section 1A is shown on Figure 2-3. Static water levels recorded on October 10, 1996 indicate that the lower two feet of Fill located near the sheetpiling is saturated and that there is a slight upward vertical gradient at this position, indicating flow around the bottom of the piling. Moving away (west) from the piling, the Fill is unsaturated. Piezometer B1A-2 is dry, but is positioned slightly above a 1.5 foot thick sand seam which is described on the Boring Log as wet (water bearing). At the B1A-3 Piezometer, the static water level in glacial till is at a depth of 4.6 feet below ground surface.

3.5 SECTION 2A SUBSURFACE CONDITIONS

Section 2A shown on Figure 2-5 is located at the entrance to Mud Island on the West Bank of the Dam at the position shown on Figures 2-1 and 2-4. The crest of the Dam at this location is wider than at other cross-section locations. A trailer which serves as an ODNR office is adjacent the section line. Seepage has been reported during high pool levels just downslope of Boring B2A-3.

The Embankment Fill at Section 2A reaches a maximum thickness of 6.0 feet and consists of sandy, clayey, silt, trace to some rock fragments. A lens of sandy silt is found from 4.0 to 6.0 feet at Boring B2A-1B near the sheetpiling.

The Foundation Till consists of glacial till characterized by sandy clay to clay, trace to some silt, trace rock fragments and mottled orange-brown to gray in the upper reaches. The till in the lower elevation of the Boring exhibits a higher silt and fine sand content, is medium to dark gray, and is weakly to moderately laminated. A two-foot thick sand and gravel lens is found at a depth of 18.0 to 20.0 feet at Boring B2A-1B. There is no evidence of a sand or gravel deposit in Boring B2A-3 where seepage reportedly has occurred.

The phreatic surface profile is presented on Figure 2-5. Potentiometric heads at Section 2A are characterized by a downward vertical gradient between the 1A (shallow) and 1B (deep) nested Piezometers. This downward gradient is atypical in comparison with the other sections investigated and is possibly due to a hydraulic connection between the Lake and the sandy silt lens found in the Fill at a depth of 4.0 to 6.0 feet in Boring B2A-1B. This could possibly be a leak in the sheetpile wall. Moving to the west along the section line, potentiometric head elevations are positioned in the glacial till and decline in the downstream direction.

3.6 SECTION 3A SUBSURFACE CONDITIONS

Section 3A shown on Figure 2-7 is located on the North Bank of the Dam as shown on Figures 2-1 and 2-6. The Borings were drilled along a state-owned fire lane which ramps up the downstream side of the Dam. The typical ground surface was surveyed adjacent the fire lane ramp and is shown on the section as the projected ground surface. A line of stressed vegetation parallel to the sheetpiling was observable in the field. This was caused by shallow burial of the masonry wall as confirmed with the drill rig.

In order to investigate the effects of both the masonry wall and the sheetpiling at this location, an additional deep Piezometer, B3A-2B, was installed downstream of the buried structure.

Section 3A shows Embankment Fill material extending to depths reaching ten feet. At Boring MW-3A-1A and 1B, drilled in the area between the sheet piling and masonry wall, the Fill consists of very stiff gravely silt which overlies loose sand and gravel. This is, in turn, underlain by sediments which accumulated upstream of the masonry wall before the sheetpiling was installed, or sediments which were used as backfill between the two structures. Downstream (northwest) of the masonry wall, the Embankment Fill consists of medium stiff to stiff, silty clay, trace to some sand and rock fragments.

The Foundation Till material at this location is interpreted to consist of glacial till found at depths of 10.0 and 6.0 feet at Borings B3A-2B and B3A-3, respectively. An organic layer is logged at depths of 13.0 and 9.0 feet in these two Borings, which, as an alternative interpretation, may represent the top of the Foundation Till at this section. The organic layer is two to three feet thick and is generally consolidated, exhibiting consistencies classified as stiff to very stiff from hand penetrometer measurements. Based on the measured consistencies and visual observation of samples from this layer, it appears that there is a relatively low percentage of organic matter in this layer in comparison to the silt and clay content. Underlying the organic soils are glacial tills consisting of silty clay, trace of fine sand to sandy clay, mottled brown and gray and becoming faintly laminated with depth.

As seen on the interpreted phreatic surface for Section 3A on Figure 2-7, a moderate head drop occurs between the Lake level and the shallow Piezometer, B3A-1A, installed in the coarse Fill material between the masonry wall and sheetpiling. Upward vertical gradients are observed at both nested Piezometer pairs at this section location. Both the lateral head loss and upward vertical gradient suggest that water is flowing beneath the bottom of the piling. Most of the Fill thickness is unsaturated. At the downstream toe of the slope (Piezometer B3A-3), the static water level is in the glacial till.

3.7 SECTION 4A SUBSURFACE CONDITIONS

Section 4A shown on Figure 2-9 is located on the North Bank of the Dam as shown on Figures 2-1 and 2-8. The B4A-series Borings were also drilled along a state-owned fire lane built on the downstream side of the Dam. The typical ground surface was surveyed adjacent to the fire lane ramp and is shown on Section 4A as the projected ground surface.

The Embankment Fill materials along this section line have an approximate maximum thickness of 8.0 feet and consist of silty clay, trace sand and rock fragments, soft to very stiff. A two foot thick sand seam was encountered at a depth of approximately 2.5 to 4.5 feet at Boring B4A-1B. This sand seam did not appear to be saturated and is discontinuous.

The Foundation Till soils at this location consists of glacial till which is silty clay, with a trace of sand and rock fragments, and soft to stiff. No laminations were observed in the till material at this location.

Three of the four Piezometers at this section are dry causing the interpretation of the position of the phreatic surface shown on Figure 2-9 to be somewhat complicated. The dry Piezometers indicate that the Fill and upper portion of the foundation soils at this location are unsaturated, which is important information for the stability analysis. Otherwise, a significant head drop is seen from the Lake level to the Embankment Fill as indicated by the dry Piezometer at B4A-1A. It is likely that an upward vertical gradient exists between the 1A (shallow) and 1B (deep) nested Piezometers, indicating flow around the sheetpiling from below.

3.8 SECTION 5A SUBSURFACE CONDITIONS

Section 5A shown on Figure 2-11 is located on the North Bank of the Dam as shown on Figures 2-1 and 2-10. The Embankment Fill materials along this section line have an approximate maximum thickness of 6.0 feet and consist of silty clay to clayey silt, with a trace to some sand, a trace of gravel, and very soft to stiff. A four foot thick sand and gravel deposit was encountered to a depth of approximately four feet at Boring B5A-1B. This coarse grained deposit does not appear to be saturated and is discontinuous.

The Foundation Till at this location consists of glacial till which is silty clay, trace of sand and rock fragments, soft to stiff. No laminations were observed in the till material at this location. A discontinuous silty sand layer in the till unit is found at a depth of approximately 18.0 to 20.0 feet.

Two of the four Piezometers at this section are dry. However, data from the remaining two Piezometers are sufficient to substantiate the interpreted phreatic surface position. The dry Piezometers indicate that the Fill and upper portion of the foundation soils at this location are unsaturated, which is important information for the stability analysis. This section also exhibits a significant head drop from the Lake level to the Fill soils behind the sheetpiling. An upward vertical gradient exists between the 1A (shallow) and 1B (deep) nested Piezometer positions, indicating flow around the sheetpiling from below.

4.0 INTERPRETATION AND ANALYSIS

We have interpreted the data in other reports made available by the ODNR along with the data obtained in the field and laboratory as part of this investigation. These data have all been interpreted from the perspective of assessing the stability of the Dam as it exists today (the "Before" condition) and when Fill is added to the crest and a postulated PMF condition occurs, (the "After" condition). We have already discussed, in previous sections, our interpretation of the seepage conditions in the Dam from the perspective of the potential for piping and the location of the phreatic surface. In this section, we report our interpretation of the shear strength of the Embankment Fill and the Foundation Till and the results of our stability analysis.

4.1 SOIL STRENGTH PARAMETERS

4.1.1 General Remarks

Before discussing the details of the interpretation of the geotechnical engineering conditions of the Dam and the stability analysis, we provide a few general remarks pertaining to this effort. First, we wish to state that we are concerned with a deep catastrophic failure of the Dam, the type of failure that would lead to loss of life and severe property damage. We do not deal with shallow sloughs that are highly dependent on local surficial soil conditions, vegetation, tree growth, local drainage and contouring and relatively small excavations.

Secondly, even though our main concern is with deep failure surfaces, we do not confine the analysis to postulated circular failure surfaces as investigated by DLA and WSGA. We also deal with non-circular surfaces and/or wedge type failures.

Thirdly, in assessing the shear strength of the Embankment Fill at this particular Dam, we note that the consistency of the silty clay and clay samples is generally medium stiff to stiff or very stiff if the Standard Penetration Test (SPT) blow count is used as an indirect measurement. On the other, hand the pocket penetrometer test, when run at three or four different points on a recovered split barrel sample, suggests consistency descriptors ranging from soft to stiff for the same sample.

Both tests are crude and not a true indicator of shear strength. The SPT, being conducted at the bottom of a Boring, yields results associated with a confined environment, an important consideration where silt-size particles are concerned. On the other hand, the pocket penetrometer allows one to consider the details of a particular sample. Of course, the triaxial tests give the best indication of shear strength so long as the samples are not biased toward the most competent material. We have been careful to avoid such a bias, but we would also note that this particular Embankment Fill is not layered, and therefore, relatively thin weak continuous layers are not a consideration at this particular Dam.

Fourthly, in assessing the stability of dams and embankments, the conventional approach followed by the profession utilizes the Mohr-Coulomb shear strength criterion. This approach generically defines the shear strength of soil to take the following form:

$$\tau = c + \sigma' \tan \phi \qquad (1)$$

where the τ is the shear strength, **c** is the apparent cohesion, σ' is the effective normal stress acting on a failure surface, and ϕ is the friction angle between soil particles on the failure surface. For sands, the cohesion is generally zero and the friction angle is, for all practical purposes, independent of past loading history. On the other hand, for clays, such as predominate in the Dam Embankment Fill and Foundation Till, the apparent cohesion is a measurable parameter. Also, for clays, the past loading history will impact on the value of apparent cohesion and the friction angle, albeit much less for the latter. Thus, when evaluating the shear strength of a clay, one must consider the present and past state of loading experienced by the clay.

At Buckeye Lake, the foundation material is a glacial till, implying from the outset that the foundation material has been loaded by glaciers in geologic history, or over-consolidated in the jargon of the geotechnical engineer. Interestingly, we have also observed the behavior of the Embankment Fill under the confining pressure that exist in the embankment to be similar to an over-consolidated clay, implying that it was well compacted when placed, a tribute to the builders of the Dam more than 150 years ago.

The use of the Mohr-Coulomb strength criterion requires particular consideration when applied to over-consolidated clays. Specifically, one must consider the range of effective stresses likely to exist on the postulated failure surfaces. It follows that in the laboratory, one must try to simulate that particular stress state as close as practical. In addition, one must consider the rate of loading, or said another way, the rate of pore pressure build up between soil particles on the failure surface.

Finally, the shear strengths estimated by DLA based on their tests and the shear strength parameters associated with our investigation are consistent and supportive of each other when all factors are considered.

4.1.2 Laboratory Testing Program

Both the cohesion and angle of internal friction can be determined for a soil by performing a triaxial shear test in accordance with ASTM Standard Test Method D 4767 - Consolidated-Undrained Triaxial Compression Test on Cohesive Soils. As previously discussed, nine Shelby Tube samples were obtained during the field investigation. Three Samples, B2A-2, B4A-2, and B5A-3, were chosen from the Shelby Tubes for triaxial shear tests to augment the strength tests performed by DLA in 1987. Sample B2A-2 represents the Embankment Fill material and Samples B4A-2 and B5A-3 represent the glacial till comprising the Foundation of the Dam. The results of the triaxial shear tests are presented in Appendix B.

We wish to mention three significant points related to the tests conducted by our firm and those reported by DLA.

- Both sets of tests were consolidated undrained triaxial tests with pore pressure measurements following ASTM guidelines.

- Our tests were conducted with a cell pressure in the range of that expected in the field at or on the postulated failure surfaces. Previous tests were conducted at stress states higher than what currently exists on the failure surfaces in the field. This approach would suggest lower shear strength than what actually exists at low effective stresses such as exist at the Dam. Our analysis takes credit for apparent cohesion, but as a check, we also consider a pure friction material for the Embankment Fill.

- Failure of the samples tested by our laboratory was deemed by us to have occurred at a strain level of in the range of 15 to 20 percent, whereas failure of the previous samples was deemed to have occurred when the ratio of the principal stresses reached a maximum, usually in the range of a few percent strain. For dams, the profession, including most review agencies, usually consider strain levels in the range of 15 to 20 percent, whereas for building foundations, shear strength defined by the maximum principal stress ratio is more appropriate.

- Both sets of tests were conducted under saturated conditions by first saturating the sample in the laboratory. On the other hand, the critical failure surfaces associated with the stability analysis are generally above the phreatic surface, suggesting that the soil elements along the failure surface are unsaturated. The use of saturated shear strengths for unsaturated conditions is usually overly conservative.

4.1.3 Interpretation of Strength Parameters for Stability Analysis

The cohesion and angle of internal friction for both the Embankment Fill and the Foundation Till were interpreted from a data set that combined the results of our tests and those of DLA. The DLA tests were reinterpreted to define failure in the range of 15 to 20 percent. This approach allowed for an interpretation of a broad range of test results from numerous locations along the entire length of the Dam. The Mohr Circles for each sample, at varying confining pressures, were plotted for both the effective and total stresses for the Embankment Fill and the Foundation Till (see Figure 4-1). The summary of the effective and total stress parameters for the Embankment Fill and Foundation Till are presented on Tables 4-1 and 4-2, respectively.

Several lines, denoted as A, B, C, etc., on Figure 4-1, tangent to and connecting the Mohr Circles, were drawn to represent several cases of cohesion and the angle of internal friction for the Embankment Fill and Foundation Till materials. Circles judged to be outliers or inconsistent with the bulk of the data are reported for completeness. We considered all the strength data, plus the Standard Penetration Test blow counts, the pocket penetrometer tests, the Atterberg Limits, the grain size variation and the moisture content, in arriving at a set of parameters that we judge to conservatively represent the available shear strength in the Embankment Fill and the Foundation Till, taking into account the scatter in the data, the presence of soft zones and/or organic pockets and likely variation across the 4.2 miles of Dam Embankment. An enveloping failure line, consistent with the Mohr Coulomb theory, chosen to be the most representative of the Embankment Fill and Foundation Till, was used to determine the cohesion and angle of internal friction. The effective stress cohesion and angle of internal friction and the total stress cohesion and angle of internal friction selected for stability analysis are presented on Table 4-3.

We also make the following observations:

- At the low effective stresses considered to exist along the postulated failure surfaces, both the Embankment Fill and the Foundation Till behave as over-consolidated clays when loaded in shear. We would emphasize that this type behavior is a function of the relative stress states. At much higher stress states, such as could be induced in a laboratory, the Embankment Fill may act as normally consolidated.

- There is little difference between the effective stress friction angle and the total stress friction angle, while there is a major difference in the two cohesion values. This is consistent with the concept that the friction angle is more of a material property while cohesion is, to a very large degree, a manifestation of past loading history.

- Based on the analytical results from our investigation, coupled with the combined analysis previously discussed, we account for apparent cohesion in our slope stability analyses. Results of the strength tests, grain size analyses, Atterberg Limits, and permeability support the position that the Embankment Fill and the Foundation Till are clays which exhibit an apparent cohesion.

- The parameters reported in Table 4-3 for effective cohesion and effective friction angle are recommended as being applicable to the stability analysis reported below. It is noted that on Table 4-3, we also report values for total stress conditions. Finally, in our stability analysis, we consider a hypothetical purely friction Embankment Fill having a friction angle of 39.5 degrees and without cohesion, a hypothesis to which we do not subscribe but we report to eliminate controversy.

4.1.4 Loading Cases for Slope Stability Analysis

To assess the slope stability of the Dam, we considered the cases listed on Tables 4-4 and 4-5. It is noted that we performed "Before" and "After" analysis at five sections plus four additional cases (earthquake and downstream flooding "Before" and "After") at the section with the lowest factor of safety under static, non-downstream flooding conditions. At this same section with the lowest factor of safety, we also analyzed the stability of the Embankment Fill with a structure constructed within the downstream slope. We considered "Before" and "After" situations as well as an earthquake and downstream flooding. Finally, we modeled Section 2 from the DLA study using our strength parameters. The total number of cases considered is 48.

4.2 SLOPE STABILITY ANALYSES

Using the geologic cross sections and the soil strength parameters previously presented, slope stability models were developed for the various cross sections utilizing the University of Texas Analysis of Slopes - Version 3 (UTEXAS3) software program. This section provides discussions of the following:

- Slope Stability Model Development;
- Seepage Evaluation; and
- Performance of the Slope Stability Analysis.

4.2.1 Slope Stability Model Development

Slope stability models were developed using the UTEXAS3 software program. UTEXAS3 was developed by Stephen G. Wright in May 1990 with subsequent revisions in July 1991 and September 1991. The program calculates a factor of safety using the most commonly accepted equation for slope stability analysis:

$$\mathbf{F} = s/\tau \qquad (2)$$

where **F** is the factor of safety against catastrophic stability failure, **s** is the shear strength along the postulated failure surface available to prevent failure of the soil (often called the resisting force), and τ is the shear stress tending to cause failure, often called the driving force.

The factor of safety can be calculated using either postulated circular or noncircular failure surfaces. The failure surfaces can be specified as single, individual surfaces, or one can specify an automatic search to produce the most critical shear surface with the minimum factor of safety. The slope geometry and soil profiles are input to represent the various layers (soil types), as well as soil properties (unit weight, cohesion, angle of internal friction), and the phreatic surface. External loads, both point (concentrated) and surface (distributed) forces, can be utilized to represent stockpiled materials, vehicles, and, supported foundations.

Preliminary slope stability models were developed for each of the five cross sections (see Figures 2-3, 2-5, 2-7, 2-9, and 2-11). From these preliminary models, the cross section exhibiting the lowest factor of safety was used to develop more enhanced stability analyses. In addition, slope stability models of Section 2 from the DLA study, which produced their lowest factor of safety, were developed as a sensitivity analysis for the

UTEXAS3 software program. A detailed discussion of the performance of the slope stability analyses and the results of the stability analyses are presented in Section 4.2.3.

4.2.2 Seepage Evaluation

Piezometers were installed in the Dam Embankment Fill at locations shown on the cross sections (see Figures 2-3, 2-5, 2-7, 2-9, and 2-11), and as discussed in Section 3.1. Water level readings were taken from the Piezometers at various times and are compiled in Table 3-4. The water level readings were used to construct the phreatic surface through the Dam Embankment for the normal Lake level.

The hydraulic conductivity (permeability, k) of the Embankment Fill and Foundation Till was analyzed for four representative samples. The permeability expresses the ease with which water passes through a soil. The results of the permeability analyses (Table 2-3) indicate that both the Embankment Fill and the Foundation Till exhibit very low permeabilities, 6.5×10^{-7} cm/sec for the Embankment Fill and 3.7×10^{-6} cm/sec to 7.7×10^{-8} cm/sec for the Foundation Till. These permeability values are indicative of nearly impervious silts and clays.

Results of water level readings from the Piezometers indicate a predominate deep phreatic surface residing within the Foundation Till and occasionally reaching into the Embankment Fill at isolated areas. Based on the nature of the Embankment Fill and Foundation Till materials, very little increase in the height of the phreatic surface is expected when the Lake is surcharged by the PMF storm event.

We estimate that if the un-discharged volume of runoff produced by the PMF storm event were allowed to pool behind the Dam Embankment Fill for a period of up to two weeks prior to discharge, the change in the phreatic surface would be between one foot and three feet, depending on local conditions and antecedent conditions. This estimate considers the highest permeability value measured in the laboratory and the level changes in the Piezometers associated with Lake level fluctuations during the limited time period of our field investigation. This scenario of allowing the PMF storm event to pool behind the Dam for a long period of time will not actually be realized, as the runoff will be released from the Dam spillways during and immediately after the storm event.

4.2.3 Performance of the Slope Stability Analysis

Slope stability analysis of the Dam was performed for various loading conditions and soil strength parameters to provide a comprehensive evaluation of the Embankment Fill and Foundation Till . A summary of the loading conditions and soil strength parameters is presented in Tables 4-4 and 4-5. The resulting factor of safety calculated under each load condition and soil strength is also presented in Tables 4-4 and 4-5. The following narrative presents a discussion of the UTEXAS3 software sensitivity analysis, and descriptions of the load conditions and soil strength parameters with corresponding slope stability analysis results.

4.2.3.1 UTEXAS3 Sensitivity Analysis

Slope stability analyses were performed for Section 2, identified in the DLA Study as the "worst" section, utilizing the UTEXAS3 software. This was accomplished by creating an input file, compatible with the UTEXAS3 software, that modeled the DLA Section 2 for both the "Before" and "After" scenarios, and comparing the results determined by the UTEXAS3 software.

The DLA failure surfaces determined to be the most critical (lowest factor of safety) and the soil strength parameters were input to serve as a "check" of the UTEXAS3 software. For the "Before" case, DLA reported a factor of safety of 1.35, and the UTEXAS3 software calculated a factor of safety of 1.49. The "After" case had a factor of safety of 1.10 for DLA and 1.03 for UTEXAS3. The similarity in the results provides a reasonable surety that the UTEXAS3 software analyses stability in a manner analyses comparable to the DLA software.

4.2.3.2 Stability Analyses for this Investigation

Five Sections, 1A, 2A, 3A, 4A, and 5A, were modeled for slope stability analyses using the UTEXAS3 software. Each section was subjected to two load conditions ("Before" and "After") using three distinct soil strength parameter conditions for a total of six individual, general cases for each section (see Table 4-4). The general cases modeled for each of the five cross sections can be described as follows:

- Case 1-B: This is a "Before" case where the Lake is at normal pool (El 892.25 ft.), the phreatic surface is as measured in the field in 1996, the effective stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, and no tailwater is present at the downstream toe of the Dam.

- Case 2-B: This is a "Before" case where the Lake is at normal pool, the phreatic surface is as measured in the field in 1996, the total stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, and no tailwater is present at the downstream toe of the Dam.

- Case 3-B: This is a "Before" case where the Lake is at normal pool, the phreatic surface is as measured in the field in 1996, total stress soil strength parameters are assumed for the Foundation Till and a cohesionless ($C = 0.0$ tsf; $\phi = 39.5^{\circ}$) material is assumed for the Embankment Fill, and no tailwater is present at the downstream toe of the Dam.

- Case 1-A: This is an "After' case where the Embankment and Lake level are raised to the PMF level (897.0 ft.), the phreatic surface is raised to account for the PMF, the effective stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, and no tailwater is present at the downstream toe of the Dam.

- Case 2-A: This is an "After" case where the Embankment and Lake level are raised to the PMF level (897.0 ft.), the phreatic surface is raised to account for the PMF, the total stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, and no tailwater is present at the downstream toe of the Dam.

- Case 3-A: This is an "After" case where the Embankment Fill and Lake level are raised to the PMF level (897.0 ft.), the phreatic surface is raised to account for the PMF, the total stress soil strength parameters are assumed for the Foundation Till and a cohesionless (C = 0.0 tsf; $\phi = 39.5^{\circ}$) material is assumed for the Embankment Fill, and no tailwater is present at the downstream toe of the Dam.

Upon reviewing the results of the slope stability analyses, the following additional load condition and soil strength parameter cases (see Table 4-4) were analyzed for the particular section determined to exhibit the most critical failure surface (lowest factor of safety):

- Case 4-B: This is a "Before" case where the Lake is at normal pool, the phreatic surface is as measured in the field in 1996, the total stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, the occurrence of an earthquake with a peak horizontal ground acceleration of 0.10g, and no tailwater is present at the downstream toe of the Dam.

- Case 5-B: This is a "Before" case where the Lake is at normal pool, the phreatic surface is as measured in the field in 1996, the effective stress soil strength parameters are assumed for both the Embankment Fill and the Foundation Till, and the tailwater is present at El 890.0 ft. at the downstream toe of the Dam. This case would be associated with downstream flooding during a major storm event.

- Case 4-A: This is an "After" case where the Embankment and Lake level are raised to the PMF level, the phreatic surface is raised to account for the PMF, the total stress soil strength parameters are assumed for both the Embankment Fill and the Foundation Till, the occurrence of an earthquake with a peak horizontal acceleration of 0.10g, and no tailwater is present at the downstream toe of the Dam.

- Case 5-A: This is an "After" case where the Embankment and Lake level are raised to the PMF level, the phreatic surface is raised to account for the PMF, the effective stress soil strength parameters are assumed for both the Embankment Fill and the Foundation Till, and tailwater is present at El 890.0 ft. at the downstream toe of the Dam.

- Case 6-B: This is a "Before" case where the Lake is at normal pool (El 892.25 ft.), a structure is modeled into the downstream slope, the phreatic surface is as measured in the field in 1996, the effective stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, and no tailwater is present at the downstream toe of the Dam.

- Case 7-B: This is a "Before" case where the Lake is at normal pool, a structure is modeled into the downstream slope, the phreatic surface is as measured in the field in 1996, the total stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, and no tailwater is present at the downstream toe of the Dam.

- Case 8-B: This is a "Before" case where the Lake is at normal pool, a structure is modeled into the downstream slope, the phreatic surface is as measured in the field in 1996, total stress soil strength parameters are assumed for the Foundation Till and a cohesionless ($C = 0.0$ tsf; $\phi = 39.5^\circ$) material is assumed for the Embankment Fill, and no tailwater is present at the downstream toe of the Dam.

- Case 9-B: This is a "Before" case where the Lake is at normal pool, a structure is modeled into the downstream slope, the phreatic surface is as measured in the field in 1996, the total stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, the occurrence of an earthquake with a peak horizontal ground acceleration of 0.10g, and no tailwater is present at the downstream toe of the Dam.

- Case 10-B: This is a "Before" case where the Lake is at normal pool, a structure is modeled into the downstream slope, the phreatic surface is as measured in the field in 1996, the effective stress soil strength parameters are assumed for both the Embankment Fill and the Foundation Till, and the tailwater present is at El 890.0 ft. at the downstream toe of the Dam. This case would be associated with downstream flooding during a major storm event.

- Case 6-A: This is an "After' case where the Embankment Fill and Lake level are raised to the PMF level (897.0 ft.), a structure is modeled into the downstream slope, the phreatic surface is raised to account for the PMF, the effective stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, and no tailwater is present at the downstream toe of the Dam.

- Case 7-A: This is an "After" case where the Embankment and Lake level are raised to the PMF level (897.0 ft.), a structure is modeled into the downstream slope, the phreatic surface is raised to account for the PMF, the total stress soil strength parameters are assumed for both the Embankment Fill and Foundation Till, and no tailwater is present at the downstream toe of the Dam.

- Case 8-A: This is an "After" case where the Embankment and Lake level are raised to the PMF level (897.0 ft.), a structure is modeled into the downstream slope, the phreatic surface is raised to account for the PMF, the total stress soil strength parameters are assumed for the Foundation Till and a cohesionless (C = 0.0 tsf; $\phi = 39.5^{\circ}$) material is assumed for the Embankment Fill, and no is tailwater present at the downstream toe of the Dam.

- Case 9-A: This is an "After" case where the Embankment and Lake level are raised to the PMF level, a structure is modeled into the downstream slope, the phreatic surface is raised to account for the PMF, the total stress soil strength parameters are assumed for both the Embankment Fill and the Foundation Till, the occurrence of an earthquake with a peak horizontal acceleration of 0.10g, and no tailwater is present at the downstream toe of the Dam.

- Case 10-A: This is an "After" case where the Embankment and Lake level are raised to the PMF level, a structure is modeled into the downstream slope, the phreatic surface is raised to account for the PMF, the effective stress soil strength parameters are assumed for both the Embankment Fill and the Foundation Till, and tailwater is present at El 890.0 ft. at the downstream toe of the Dam.

The slope stability analysis results for each of the five cross sections is discussed in the following sections:

4.2.3.3 Section 1A Slope Stability Analysis

The slope stability analysis results for Section 1A indicate a factor of safety of 5.23 for the "Before" effective stress case, and 5.28 for the "Before" total stress case. These factors of safety are well above the accepted factor of safety of 1.5 for the static evaluation of dam stability. Case 3-B indicates a factor of safety of 3.78 for cohesionless Embankment Fill. This "zero" cohesion condition in the Embankment Fill even produces a factor of safety that is well above the accepted 1.5 for static evaluations.

The results of the "After" scenario (4.55, effective and 4.60, total) produce factors of safety that are less than the "Before" scenario, but these factors of safety are still well above the accepted 1.5 for static evaluations. The decrease in the factor of safety for the "After" scenario is to expected due to the presence of the additional fill on the Embankment.

The increase in the factor of safety for the cohesionless Embankment from 3.78 to 3.94 was investigated and found to be the result of slightly higher shear strength on the uppermost part of the failure surface associated with the increased effective stresses. As noted elsewhere, we do not subscribe to the concept of a cohesionless Embankment Fill material, but we report the results to eliminate controversial discussions and "what if" questions. Indeed, one would not add fill to the heel of an embankment to make it safer and, therefore, these results for this specific case, while generated by a detailed computer analysis, should not be taken as a general notion that a dam is generally safer from a slope stability perspective with the increased crest level.

It is important to note that the increase in the height of the phreatic surface does not have a significant effect on the factor of safety. This behavior is verified by no significant decrease in the value of the factor of safety when performing the slope stability analysis with the Embankment at the normal ("Before") pool level and the raised phreatic surface. This condition was observed for each of the five cross sections evaluated and is to be expected because the failure surfaces generally do not penetrate below the raised phreatic surface. In those cases where it does penetrate below the phreatic surface, the depth of penetration is small and only a short section of the failure surface is submerged.

When compared to the slope stability analysis results of the other four cross sections, Section 1A is not the critical section and therefore, no additional cases were performed for Section 1A. The failure surfaces associated with the lowest factors of safety calculated for Section 1A are presented on Figures 4-2 and 4-3.

4.2.3.4 Section 2A Slope Stability Analysis

The slope stability analysis results for Section 2A indicate a factor of safety of 4.83 for the "Before" effective stress case, and 4.90 for the "Before" total stress case. These factors of safety are well above the accepted factor of safety of 1.5 for the static evaluation of dam stability. Case 3-B indicates a factor of safety of 3.01 for cohesionless Embankment Fill. This "zero" cohesion condition in the Embankment Fill even produces a factor of safety that is well above the accepted 1.5 for static evaluations.

The results of the "After" scenario (4.02, effective stress and 4.07, total stress) produce factors of safety that are less than the "Before" scenario, but these factors of safety are still well above the accepted 1.5 for static evaluations. The decrease in the factor of safety for the "After" scenario is to be expected due to the presence of the additional fill on the

Embankment . At this Section, the factor of safety for the cohesionless embankment decreased slightly from 3.01 to 2.94.

When compared to the slope stability analysis results of the other four cross sections, Section 2A is not the critical section and therefore, no additional cases were performed for Section 2A. The failure surfaces associated with the lowest factors of safety calculated for Section 2A are presented on Figures 4-4 and 4-5.

4.2.3.5 Section 3A Slope Stability Analysis

The slope stability analysis results for Section 3A indicate a factor of safety of 3.09 for the "Before" effective stress case, and 3.11 for the "Before" total stress case. These factors of safety are well above the accepted factor of safety of 1.5 for the static evaluation of dam stability. Case 3-B indicates a factor of safety of 2.91 for cohesionless Embankment Fill. This "zero" cohesion condition in the Embankment Fill even produces a factor of safety that is well above the accepted 1.5 for static evaluations.

The results of the "After" scenario (2.45, effective stress and 2.48, total stress) produce factors of safety that are less than the "Before" scenario, but these factors of safety are still well above the accepted 1.5 for static evaluations. The decrease in the factor of safety for the "After" scenario is to be expected due to the presence of the additional fill on the Embankment. The failure surfaces associated with the lowest factors of safety calculated for Section 3A are presented on Figures 4-6 and 4-7. At this section, the factor of safety for the cohesionless Embankment decreased from 2.91 to 2.71 as the crest level was raised.

When compared to the slope stability analysis results of the other four cross sections, Section 3A was determined to be the critical section. Four additional loading conditions and corresponding soil strength parameters were analyzed for Section 3A. These additional analyses included, for both the "Before" and "After" cases, an earthquake evaluation and the presence of tailwater at the downstream toe of the Embankment.

The earthquake evaluation was performed by initiating a horizontal acceleration of 0.10g in addition to the normal vertical loads and stresses utilized in the software. The results of the earthquake evaluation for the "Before" case indicate a factor of safety of 2.27, and a factor of safety of 1.89 for the "After" case. The factor of safety for the "After" case is lower than the factor of safety for the "Before" case which is to be expected, once again, due to the increased Embankment Fill. The factor of safety for both cases is above the accepted factor of safety for earthquake evaluation of 1.0. The failure surfaces associated with the earthquake evaluation for Section 3A are presented on Figure 4-12.

The tailwater evaluation was performed by simulating the presence of water at El 890.0 ft. at the downstream toe of the Embankment associated with flows of nearby streams or creeks. The results of the tailwater evaluation for the "Before" case indicate a factor of safety of 3.77 and a factor of safety of 2.86 for the "After" case. Once again, as expected, the factor of safety for the "After" case was lower than the factor of safety for the "Before" case.

We note that the factor of safety for both the "Before" and "After" cases is slightly higher than the factor of safety for each case without the presence of tailwater at the downstream toe of the embankment. Due to the low permeabilities observed for both the Embankment Fill and Foundation Till, the tailwater would have little, if any effect on the height of the phreatic surface unless the tailwater remained in place for an exceptionally long period of time. The tailwater level will diminish as the downstream flooding conditions are corrected, and therefore, would not be present at the toe of the embankment for periods of time sufficient to influence the phreatic surface, the factor of safety against stability failure. Consequently, the tailwater, not being hydraulically connected to the phreatic surface, acts as a temporary weight at the toe, much like an earthen berm. We would emphasize that the presence of tailwater at the downstream toe of the Embankment would eventually diminish the integrity of the Dam and efforts through local agencies should be made to control flooding conditions downstream of the Dam to minimize or eliminate, if possible, this situation. The failure surfaces associated with the tailwater evaluation for Section 3A are presented on Figure 4-13.

4.2.3.6 Section 3A with Structure on Downstream Slope-Stability Analysis

Major segments of the Dam have been "abused" with the placement of structures within the downstream slope. More specifically, property owners have excavated the downstream slope from the toe to the downstream edge of the crest and replaced the Embankment Fill with a basement foundation. The basement floors are generally concrete and the basement walls are either concrete masonry units or reinforced concrete. No records of design, construction, and/or construction quality assurance are available.

We assessed the stability of this configuration by replacing the excavated earth with a solid block to simulate the emplaced structure. The interface between the block and the foundation is interpreted to have a friction angle of 39.5° and the weight of the block is equivalent to the weight of a two story home. The one story basement wall on the Dam side of the basement is capable of withstanding the current at rest soil conditions. For the sliding cases, both static and dynamic, we interpret the pressures to be active plus a dynamic component to be about equal to the existing at-rest pressures.

Consequently, our analyses assume that the emplaced basement is consistent with conventional housing design and construction practice. The professional's experience indicates that basement walls rarely fail during earthquake loading and then only under high magnitude events. Hence, it is our view that generally speaking, the basement walls will not fail under earthquake and that breach of the Dam caused by the failure of a basement wall is highly unlikely.

We assessed the margin of safety against catastrophic failure of the foundation of the emplaced house/Dam system with an analysis of Section 3A by considering a structure emplaced in the downstream slope of the Dam at this "worst" cross section. Our results indicate a factor of safety of 3.09 for the "Before" effective stress case, and 3.11 for the "Before" total stress case. These factors of safety are well above the accepted factor of safety of 1.5 for the static evaluation of dam stability. Case 3-B indicates a factor of safety of 2.91 for cohesionless Embankment Fill. This "zero" cohesion condition in the

Embankment Fill even produces a factor of safety that is well above the accepted 1.5 for static evaluations.

The results of the "After" scenario (2.45, effective stress and 2.48, total stress) indicate factors of safety that are less than the "Before" scenario, but these factors of safety are still well above the accepted 1.5 for static evaluations. The decrease in the factor of safety for the "After" scenario is to be expected due to the presence of the additional fill on the embankment. The failure surfaces associated with the lowest factors of safety calculated for Section 3A with an emplaced structure are presented on Figures 4-6 and 4-7. At this section, the factor of safety for the cohesionless embankment decreased from 2.91 to 2.71 as the crest level was raised.

Four additional loading conditions and corresponding soil strength parameters were analyzed for Section 3A with the structure emplaced in the downstream slope. These additional analyses included, for both the "Before" and "After" cases, an earthquake evaluation and the presence of tailwater at the downstream toe of the embankment.

The earthquake evaluation was performed by initiating a horizontal acceleration of 0.10g in addition to the normal vertical loads and stresses utilized in the software. The results of the earthquake evaluation for the "Before" case indicate a factor of safety of 2.27, and a factor of safety of 1.89 for the "After" case. The factor of safety for the "After" case is lower than the factor of safety for the "Before" case which was expected once again due to the increased Embankment Fill. The factor of safety for both cases is above the accepted factor of safety for earthquake evaluation of 1.0. The failure surfaces associated with the earthquake evaluation for Section 3A with a structure emplaced in the downstream slope are presented on Figure 4-12.

The tailwater evaluation was performed by simulating the presence of water at El 890.0 ft. at the downstream toe of the embankment associated with flows of nearby streams or creeks. The results of the tailwater evaluation for the "Before" case indicates a factor of safety of 3.77 and a factor of safety of 2.80 for the "After" case. Once again, as generally expected, the factor of safety for the "After" case was lower than the factor of safety for the "Before" case.

We note that the factor of safety for both the "Before" and "After" cases are slightly higher than the factor of safety for each case without the presence of tailwater at the downstream toe of the embankment. Due to the low permeabilities observed for both the Embankment Fill and Foundation Till, the tailwater would have little, if any effect on the height of the phreatic surface unless the tailwater remained in place for an exceptionally long period of time. The tailwater level diminishes as the downstream flooding conditions are corrected, and therefore, would not be present at the toe of the embankment for periods of time sufficient to influence the phreatic surface, and the factor of safety. Consequently, the tailwater, not being hydraulically connected to phreatic surface, acts as a temporary weight at the toe, much like an earthen berm. We would emphasize that the presence of tailwater at the downstream toe of the Embankment would eventually diminish the integrity of the Dam and therefore, efforts through local agencies should be made to control flooding conditions downstream of the Dam to minimize or eliminate, if possible, this situation from occurring. The failure surfaces associated with the tailwater evaluation for Section 3A with an emplaced structure are presented on Figure 4-17.

4.2.3.7 Section 4A Slope Stability Analysis

The slope stability analysis results for Section 4A indicate a factor of safety of 3.56 for the "Before" effective stress case, and 3.65 for the "Before" total stress case. These factors of safety are well above the accepted factor of safety of 1.5 for the static evaluation of dam stability. Case 3-B indicates a factor of safety of 3.00 for cohesionless Embankment Fill. This "zero" cohesion condition in the Embankment Fill even produces a factor of safety that is well above the accepted 1.5 for static evaluations.

The results of the "After" scenario (2.41, effective stress and 2.46, total stress) produce factors of safety that are less than the "Before" scenario, but these factors of safety are still well above the accepted 1.5 for static evaluations. The decrease in the factor of safety for the "After" scenario is to be expected due to the presence of the additional fill on the embankment. At this section we note that the factor of safety increased slightly for the cohesionless Embankment (from 3.00 to 3.05) as a result of a slight increase in the shear strength associated with slightly higher effective stresses. We refer to our discussion of Section 1A, where this also occurred.

When compared to the slope stability analysis results of the other four cross sections, Section 4A is not the critical section. No additional cases were performed for Section 4A. The failure surfaces associated with the lowest factors of safety calculated for Section 4A are presented on Figures 4-8 and 4-9.

4.2.3.8 Section 5A Slope Stability Analysis

The slope stability analysis results for Section 5A indicates a factor of safety of 7.17 for the "Before" effective stress case, and 7.23 for the "Before" total stress case. These factors of safety are well above the accepted factor of safety of 1.5 for the static evaluation of dam stability. Case 3-B indicates a factor of safety of 4.09 for cohesionless Embankment Fill. This "zero" cohesion condition in the Embankment Fill even produces a factor of safety that is well above the accepted 1.5 for static evaluations.

The results of the "After" scenario (4.43, effective stress and 4.47, total stress) produce factors of safety that are less than the "Before" scenario, but these factors of safety are still well above the accepted 1.5 for static evaluations. The decrease in the factor of safety for the "After" scenario is to be expected due to the presence of the additional fill on the embankment. At this section, the factor of safety decreased from 4.09 to 2.66 for the cohesionless Embankment as the crest level was raised.

When compared to the slope stability analysis results of the other four cross sections, Section 5A is not the critical section. No additional cases were performed for Section 5A. The failure surfaces associated with the lowest factors of safety calculated for Section 5A are presented on Figures 4-10 and 4-11.

4.2.3.9 Dodson-Lindblom Associates Stability Analysis

Dodson-Lindblom Associates utilized drained strength parameters with no apparent cohesion for the Embankment Fill and Foundation Till when performing their stability analysis of Section 2 in the 1987 study. As previously discussed, our findings indicate that the Embankment Fill and Foundation Till soils exhibit apparent cohesion at relatively low overburden stress levels based on the results of the triaxial tests, and evaluation of the Mohr Circles. Using the model of DLA's Section 2 from the sensitivity analysis, we performed the slope stability of Section 2 using the values for cohesion and the angle of internal friction developed for our stability analyses.

Using the model of DLA's Section 2, including their location of the phreatic surface, and our strength parameters for the Embankment Fill and Foundation Till, the stability analysis was performed for both the "Before" and "After" loading conditions. Factors of safety of 11.6 and 10.86 for effective stress and total stress, respectively, were obtained for the "Before" load conditions. For the "After" load condition, factors of safety of 5.85 and 5.58 for effective stress and total stress, respectively, were obtained. Once again, this correlates with lower factors of safety for the "After" case due to the increased Embankment Fill. On the other hand, it would appear that the DLA failure surfaces are probably not the worst cases when our recommended strength parameters are used.

It is important to note that the height of the phreatic surface used in the DLA model of Section 2 is substantially higher than the phreatic surface used in our models. The phreatic surface modeled for the "After" load condition has contact points with the Lake and the tailwater at the downstream toe of the embankment. This location of the phreatic surface dramatically influences the difference in the values of the factor of safety between the "Before" and "After" load conditions.

In addition to the previous load conditions, we modeled the Embankment Fill as a cohesionless material ($C = 0.0$ tsf; $\phi = 39.5^{\circ}$). The analysis indicates factors of safety of 11.2 and 4.99 for the "Before" and "After" cases, respectively. These results indicate that even with cohesionless Embankment Fill, the Dam is stable at DLA's Section 2 for both the "Before" and "After" cases.

5.0 EVALUATION OF DAM SAFETY ISSUES

This Section deals with three primary issues related to the long term safety of Buckeye Lake Dam. While these issues have an indirect impact on stability, more importantly, they have a direct impact on piping, overtopping and/or the behavior of the new and existing retaining walls. Hence, there is a need to address these issues during and subsequent to Phase III remediation.

5.1 TREES AND LANDSCAPING ON THE DAM CREST

The crest of the Dam has been "abused" by allowing trees, some having diameters in excess of 30 inches, to grow on the crest and downstream slope. Trees have a direct impact on dam safety from the perspective that root structure provides pathways for piping to develop and overturned trees can cause large voids to develop, leading to overtopping during rain events with high pool levels. Consequently, we have the following recommendations pertaining to trees, landscaping, and hardscaping.

1. All trees and stumps, regardless of diameter, that are rooted in the crest or in the downstream slope should be removed. Stumps should be removed and roots should be "chased" to a point where the diameter is less than two inches and removed. Root grindings and cuttings should be removed from the stump excavation to the maximum degree practical. The stump excavation should be backfilled with clay compacted to 95 percent of the maximum dry density as determined by the Standard Proctor Method and within two percent of the optimum moisture content on the wet side.

2. Small diameter trees having a maximum diameter on the order of two (2) inches measured at a height of 54 inches can be placed and maintained in planters that do not allow roots to penetrate into the Dam crest or downstream slope. Plantings on the crest and downstream slope should be limited to grass and small flowers. Shrubbery and small bushes and trees should be prohibited.

3. A ten foot wide clear buffer zone on the upstream side of the crest and parallel to the sheet pile wall should be cleared and maintained free of all hardscaping except for the following permissible materials:

   - Un-cemented stone chips
   - Grass and flowers
   - Sand and gravel
   - Concrete pavers (less than 2' by 2')
   - Wood mulch
   - Landscape timbers

Wood decks, concrete paving, brick paving, and asphalt paving are not permissible materials in the buffer zone.

All utility conduits set in the buffer zone should be encased in concrete. All water spouting should be constructed to drain to the downstream side of the Dam in such a manner that erosion does not occur. No penetrations or attachments to the new or existing wall should be allowed. All existing attachments to the existing wall should be removed and all penetrations should be sealed.

5.2 BOAT DOCKS

We have observed a large number of boat docks on the upstream side of the Dam. Some of these are on piles and others are of cantilever construction. In addition, we noticed that some docks are of suspended cantilever design with one end of the dock attached to the existing sheetpile wall. Also, we observed a boat house, lifting davits and various types of boat lifts either partially supported by the existing wall or supported on foundations embedded in the crest of the Dam. We believe that none of these features was contemplated in the original design of the existing wall or Dam. As these features are a potential threat to dam safety, most should be removed and replaced with designs that are not a threat to dam safety. In addition, new and/or replacement boat docks will hinder the ability to effectively and economically perform future inspections, routine maintenance and repairs to the new sheetpile wall and Dam. We have the following specific comments regarding docking systems:

5.2.1 Pile-Supported Docks

Pile Supported Docks are acceptable so long as they do not attach to the existing or new sheetpile wall and no piles are driven into the Dam. Stairs or ramps leading between the dock and the crest should not be attached to or penetrate through the sheetpile wall. Pile-Supported Docks should be by permit only as issued by the ODNR.

5.2.2 Floating Docks

Floating Docks are acceptable so long as they do not attach to the existing or new sheetpile wall. Stairs or ramps leading between the dock and the crest should not be attached to or penetrate through the sheetpile wall. Floating Docks should be by permit only as issued by the ODNR.

5.2.3 Lifting Davits

Lifting Davits with foundations embedded in the crest should be prohibited. Temporary lifting Davits installed offshore of the existing or new sheetpile wall are acceptable so long as they do not attach to the existing or new sheetpile wall. Lifting Davits should be by permit only as issued by the ODNR.

5.2.4 Non-Suspended Cantilever Docks

Non-Suspended Cantilever Docks are docks which have a pair of anchor blocks embedded in the Dam crest and a structural steel frame that cantilevers out over the sheetpile wall into the Lake. Lifting hoists are occasionally installed at the offshore end or along the sides of the structural steel cantilever. Also, some of the cantilevers are supported with a pile strut driven into the Lake bottom to resist a portion of the vertical load and decrease the cantilever moment.

We have studied the design of this type of dock and have the following comments and recommendations:

1. From a foundation engineering perspective, and excluding considerations of dam safety, this type of dock is technically feasible. We would note that, depending on the length of the cantilever, the location of the lifting hoists, the size of the boat, and the use (or non-use) of a vertical pile strut, it may be necessary to found the anchor blocks on piles. We suspect that none of the existing Cantilever Docks include pile-supported anchor blocks.

2. From a dam safety perspective, we view Non-Suspended Cantilever Docks with anchor blocks embedded in the crest as an "abuse" of the Dam much like a house on the downstream slope, trees, etc. Therefore, this type of dock with its

concrete anchor block foundations embedded in the crest is unacceptable. We list below the following specific reasons:

- The anchor block encroaches on the integrity of the Dam. The interface between the concrete and the surrounding earth provides a preferred pathway for seepage and piping to occur.

- Docks and foundations can cause difficulty in performing inspections, maintenance, and remedial and emergency repairs of the sheet pile wall.

- Many of the existing anchor block foundations attach to the existing sheetpile wall, thus imparting a load to the wall for which it was not designed. Also, the blocks tend to increase the lateral earth pressure acting on the sheetpile wall, thus increasing the stresses in the wall and increasing the load in the tie-back anchors. These blocks should be removed and the excavation backfilled with impervious soil compacted to 95 percent of the maximum dry density as determined with the Standard Proctor method and within two percent of the optimum moisture content on the wet side.

- Even if new blocks were to be constructed away from the new wall and on piles, the potential for piping, increased lateral earth pressures and increased anchor forces still exist. Furthermore, the installation of piles, either by driving or pre-drilling, can affect the integrity of the new wall and the Dam. Piling also increases the potential for piping at depths below the normal Lake level.

3. It is our conclusion that while Non-Suspended Cantilever Docks are technically acceptable from a foundation engineering perspective, particularly with pile supported anchor blocks, they are not acceptable from a dam safety perspective. Existing docks of this type should be removed from the Dam and no new cantilever docks should be permitted.

5.2.5 Suspended Cantilever Docks

The Suspended Cantilever Docks generally consist of a deck with the shore end supported on the existing wall (and presumably on the new wall) and the offshore end supported by a suspension cable tied to a vertical column inserted into the crest of the Dam. As the shore end of this type of dock is supported on the wall and the vertical column penetrates the Dam, we recommend that this type of dock be removed and prohibited in the future.

5.2.6 Boat Houses

Boat houses should be considered on a case-by-case basis, recognizing all of the prohibitions and restrictions previously recommended. Quite frankly, we have difficulty imagining how a boat house could be designed considering all of the above. Nevertheless, we would reserve judgment until an actual design is presented to the ODNR for permitting. Indeed , boat houses that penetrate or cut into the Dam embankment or attach to the sheetpile wall should be removed and not permitted in the future.

5.3 New and Remodeled Structures on the Downstream Slope

As discussed in the context of this Report, we view the construction of homes and buildings on the downstream slope and on the crest as an "abuse" of the Dam. Our stability analysis indicates that the this type of construction impacts on the safety of the Dam. but admittedly, the margin of safety against catastrophic stability failure for the as-built construction for both the "Before" and "After" cases is satisfactory.

However, the most critical aspect of construction of these homes on the downstream slope and crest is the period of time when the excavation is open and the basement walls are being constructed. It is during this period of time that the Dam is most vulnerable to a breach and/or piping. The entire Lake is in jeopardy, and therefore, construction should be allowed to proceed only under the following conditions:

1. Local authorities should be encouraged to designate the slope and crest on the Dam as a Special Zone with respect to Building Permits and Building Regulations. Local building inspection agencies should expect to incur increased costs to monitor the construction in this Special Zone.

2. All new construction on the slope and on the crest, other than landscaping, should require a Special Building Permit based on drawings and specifications prepared and stamped by a registered professional geotechnical engineer knowledgeable and experienced in Dam construction, deep excavations, slope stability, and sheeting and shoring.

3. All new excavations on the downstream slope and on the crest, other than that associated with landscaping, should be temporarily shored using a design prepared and stamped by a registered professional geotechnical engineer.

4. New foundations and basement walls should be cast in place reinforced or reinforced concrete masonry units with vertical reinforcing steel placed in the voids and horizontal reinforcing placed in the mortar joints between courses. Foundations and basement walls should be designed by a registered professional geotechnical engineer knowledgeable and experienced in Dam construction, deep excavations, slope stability, and sheeting and shoring.

5. All excavation work and below-grade construction should be under the supervision of a registered professional geotechnical engineer following a Construction Quality Assurance (CQA) Plan approved by the local building authorities. The monitoring should be on a full time basis during the time that the excavation is open. The CQA Plan should include an emergency response plan in the event that breaching or piping begins to occur or if a storm is predicted that will cause the Lake level to rise significantly.

6. During construction of a basement excavation and basement walls, sand or sand bags should be stockpiled on site as part of an emergency response plan to mitigate the potential for a gross breach and/or piping failure.

6.0 CONCLUSIONS

Considering the results of the work performed to date by others, the 1996 field investigation and laboratory testing program, an extensive analysis of the properties of the Embankment Fill and Foundation Till, and a comprehensive stability analysis, we conclude the following:

- Based on the field observations, the relatively low head, the long seepage paths, the age of the Dam and the laboratory testing program, specifically, the properties of the soils comprising the Embankment Fill, we conclude that while there may be occasional zones of localized seepage, there is no evidence to indicate that raising the crest a few feet or a higher Lake level associated with temporary storage of the PMF will lead to a catastrophic piping failure.

- Raising the Dam crest a few feet and postulating a higher Lake level to temporarily store a PMF will not lead to stability failure of the downstream slope of the Dam. This conclusion also applies to those sections of the Dam where the downstream slope has been violated with the emplacement of a structure.

- The stability of the downstream slope of the Dam (with or without an emplaced structure) with the raised crest, postulated PMF and downstream flooding is marginally impacted, but still safe. This same conclusion applies under a postulated earthquake condition.

- The factors of safety against stability failure reported herein are substantially higher than those reported by Dodson-Lindblom Associates (DLA, 1987) and W.S. Gardner and Associates (WSGA, 1995). As all of WSGA's work is based on soil properties and assumptions regarding the phreatic surface reported by DLA; one would expect their results to be practically the same as reported by DLA. Our factors of safety are higher for the following reasons:

DCR

- Based on new laboratory test data, coupled with a reinterpretation of previous data, we find the shear strength available to resist catastrophic failure of the Embankment Fill and the Foundation Till to be higher than considered in earlier analysis.

- Based on new data obtained during this investigation from sealed Piezometers and from laboratory tests to measure permeability, we estimate that the phreatic surface will be substantially lower under the postulated PMF condition than considered in previous analysis.

We observe that the Dam has been "abused" from the perspective that the downstream toe has been excavated and replaced with structures and large trees have been permitted to grow on the crest and on the slopes. We have extensive experience evaluating the stability and safety of dams throughout the United States and, we find the "abuses" to the Buckeye Lake Dam to be some of the worst ever witnessed. We make a series of recommendations pertaining to these "abuses" as well as the matter of boat docks on the upstream side of existing and new sheet pile walls. We also conclude and advise that while the popular Non-Suspended Cantilever Docks are technically acceptable from a foundation engineering perspective, particularly with pile supported anchor blocks, they are not acceptable from a dam safety perspective. Existing docks of this type should be removed from the Dam and no new Cantilever Docks should be permitted.

Finally, we conclude that there is no reason, from a geotechnical engineering perspective, why the proposed Phase III Remediation Plan should not proceed following the normal practice of engineering and construction for dams, including a comprehensive quality control/quality assurance program.

Respectfully submitted,
Paul C. Rizzo Associates

Dr. Paul C. Rizzo, P.E.
Principal-in-Charge

Richard A. Isaac, P.E.
Project Manager

PCR/mfs

TABLES

TABLE 2-1
SOIL SAMPLES SUBMITTED FOR LABORATORY ANALYSES
BUCKEY LAKE DAM STABILITY STUDY
DNR 736 730-96-034

BORING ID	SAMPLE NO.	NATURAL MOISTURE	ATTERBERG LIMITS	SIEVE ANALYSIS	HYDROMETER	ASTM CLASSIFICATION	LABORATORY DESCRIPTION	PERMEABILITY	TRIAXIAL SHEAR STRENGTH
B1A-1B	4	X	X	X	X	X	X		
	6	X							
	7	X	X	X	X	X	X		
	9	X							
B1A-2	3	X							
	5	X	X	X	X	X	X		
	7	X							
	8	X	X	X	X	X	X		
B1A-3	3	X	X	X	X	X	X		
								X	X
								X	X
B2A-1B	2	X							
	3	X							
	4	X	X	X	X	X	X		
	8	X	X	X	X	X	X		
								X	X
								X	X
B2A-2	2	X							
	4	X	X	X	X	X	X		
	5	X	X	X	X	X	X		
								X	X
B2A-3	2	X							
	3	X	X	X	X	X	X		
	4	X							
	5	X	X	X	X	X	X		
B3A-1B	1	X	X	X	X	X	X		
	3	X							
	4	X	X	X	X	X	X		
	5	X							
B3A-2B	3	X							
	5	X	X	X	X	X	X		
	6	X							
	7	X							
	9	X	X	X	X	X	X		
								X	X
B3A-3	4	X	X	X	X	X	X		
	6	X	X	X	X	X	X		
B4A-1B	3	X							
	5	X	X	X	X	X	X		
	6	X							
	8	X							
	9	X	X	X	X	X	X		
								X	X
B4A-2	2	X	X	X	X	X	X		
	3	X							
	6	X							
								X	X
B4A-3	2	X							
	4	X	X	X	X	X	X		
	5	X							
	6	X							
	7	X	X	X	X	X	X		
B5A-1B	4	X	X	X	X	X	X		
	5	X							
	6	X							
	7	X	X	X	X	X	X		
	8	X							
	9	X	X	X	X	X	X		
B5A-2	4	X							
	5	X	X	X	X	X	X		
	8	X	X	X	X	X	X		
	9	X							
B5A-3								X	X

TABLE 2-2
SUMMARY OF DISTURBED SOIL SAMPLE LABORATORY RESULTS
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736 730-96-034

BORING NO.	SAMPLE NO.	SAMPLE DEPTH	BLOW COUNTS (N)	ATTERBERG LIMITS			NATURAL MOISTURE CONTENT (%)	USCS GROUP SYMBOL
				LL	PL	PI		
SECTION 1A								
B1A-1B	4	6.0-8.0	4	34	18	16	30.8	CL
	6	10.0-12.0	5				22.4	
	7	12.0-14.0	32	25	16	9	13.7	CL
	9	16.0-18.0	20				12.3	
B1A-2	3	4.0-6.0	12				25.6	
	5	8.0-10.0	12	31	18	13	19.7	CL
	7	12.0-14.0	4				28.3	
	8	14.0-16.0	20	24	17	7	15.6	ML/CL
B1A-3	3	4.0-6.0	5	NP	NP	NP	16.9	SM
SECTION 2A								
B2A-1B	2	2.0-4.0	6				13.3	
	3	4.0-6.0	3				23.9	
	4	6.0-8.0	5	35	17	18	20.7	SC
	8	14.0-16.0	3	32	19	13	28.3	CL
B2A-2	2	2.0-4.0	5				28.3	
	4	6.0-8.0	5	30	17	13	21.5	SC
	5	8.0-10.0	5	32	18	14	22.5	CL
B2A-3	2	2.0-4.0	4				26	
	3	4.0-6.0	5	30	21	9	32.7	CL
	4	6.0-8.0	5				27.8	
	5	8.0-10.0	6	28	22	6	25.1	ML/CL
SECTION 3A								
B3A-1B	1	0.0-2.0	4	38	21	17	37	CL
	3	14-16	5				28.9	
	4	16-18	7	38	18	20	27.8	CL
	5	18-20	7				33.1	
B3A-2B	3	4.0-6.0	6				21.9	
	5	8.0-10.0	10	42	19	23	22.7	CL
	6	10.0-12.0	6				24.6	
	7	12.0-14.0	6				29.1	
	9	16.0-18.0	5	34	16	18	26.5	CL
B3A-3	4	6.0-8.0	11	37	19	18	24.4	CL
	6	10.0-12.0	9	45	19	26	25.4	CL
SECTION 4A								
B4A-1B	3	4.0-6.0	12				22.1	
	5	8.0-10.0	4	35	19	16	29.8	CL
	6	10.0-12.0	5				36.1	
	8	14.0-16.0	3				27.9	
	9	16.0-18.0	6	35	18	17		CL
B4A-2	2	2.0-4.0	7	43	21	22	23	CL
	3	4.0-6.0	13				22.6	
	6	10.0-12.0	23				18.9	
B4A-3	2	2.0-4.0	5				27.7	
	4	6.0-8.0	15	42	22	20	26.3	CL
	5	8.0-10.0	17				25.2	
	6	10.0-12.0	9				28.2	
	7	12.0-14.0	6	36	18	18		CL
SECTION 5A								
B5A-1B	4	6.0-8.0	16				19	
	5	8.0-10.0	8	38	17	21	27.7	CL
	6	10.0-12.0	8				35.5	
	7	12.0-14.0	5	48	17	31	35.3	CL
	8	14.0-16.0	4				27	
	9	16.0-18.0	10	27	15	12	15.6	CL
B5A-2	4	6.0-8.0	8					
	5	8.0-10.0	11	32	17	15	18.5	CL
	8	14.0-16.0	8	36	17	19	25.2	CL
	9	16.0-18.0	11	33	22	11	25.7	CL

NOTES:
NP = NON-PLASTIC

Table 2-3
UNDISTURBED SOIL PERMEABILITY
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736-730-96-034

Boring No.	Sample No.	Soil Material	Depth (ft)	Permeability, k (cm/sec)
B1A-3	ST-2	Till	2 -4.5	3.7×10^{-6}
B2A-2	ST-3	Fill	4 - 6	6.5×10^{-7}
B4A-2	ST-5	Till	8 - 10	7.7×10^{-8}
B5A-3	ST-3	Till	4.5 - 7	3.7×10^{-7}

ft - Feet
cm/sec - Centimeters per Second

TABLE 2-4
SUMMARY OF PIEZOMETER
STATIC WATER LEVELS
BUCKEY LAKE DAM STABILITY STUDY
DNR 736 730-96-034

PIEZOMETER ID	COORDINATES		MONITORED INTERVAL ELEVATIONS (ft MSL)	REFERENCE POINT ELEVATON (ft MSL)	DATE 8/7/96		DATE 8/14/96		DATE 8/23/96		DATE 8/30/96		DATE 9/6/96		DATE 10/10/96		9/6/96 to 10/10/96 MAXIMUM ELEVATION FLUCUATION
	NORTHING	EASTING			DEPTH TO WATER	STATIC WATER ELEVATION	DEPTH TO WATER	STATIC WATER ELEVATION	DEPTH TO WATER	STATIC WATER ELEVATION	DEPTH TO WATER	STATIC WATER ELEVATION	DEPTH TO WATER	STATIC WATER ELEVATION	DEPTH TO WATER	STATIC WATER ELEVATION	
B1A-1A	13,188.13	11,126.61	890.73-888.43	894.73	4.38	890.35	4.58	890.15	4.86	889.87	5.25	889.48	5.16	889.57	4.77	889.96	0.39
B1A-1B	13,186.31	11,129.92	879.45-876.45	894.45	4.26	890.19	4.19	890.26	4.37	890.08	4.73	889.72	4.07	890.38	3.93	890.52	0.14
B1A-2	13,195.02	11,116.56	891.72-888.72	895.72	DRY	<886.05	DRY	<886.05	DRY	<886.05	DRY	<886.05	8.92	886.80	DRY	<886.05	0.75
B1A-3	13,203.71	11,106.65	886.11-883.31	890.31	5.58	884.73	5.63	884.68	6.10	884.21	DRY	<883.61	2.87	887.44	4.61	885.70	1.74
B2A-1A	14,387.31	11,859.01	890.4-886.4	895.40	3.96	891.44	3.99	891.41	4.10	891.30	4.23	891.17	3.73	891.67	3.85	891.55	0.12
B2A-1B	14,382.51	11,856.80	881.34-878.34	895.34	7.46	887.88	7.49	887.85	7.71	887.63	7.90	887.44	7.81	887.53	7.65	887.69	0.16
B2A-2	14,395.25	11,838.46	891.97-887.97	895.97	5.64	890.33	5.92	890.05	6.27	889.70	6.42	889.55	6.47	889.50	6.3	889.67	0.17
B2A-3	14,403.67	11,827.90	884.44-881.64	891.61	3.53	888.09	3.57	888.07	3.71	887.93	3.88	887.76	3.45	888.19	3.34	888.30	0.11
B3A-1A	15,770.50	18,087.12	891.1-881.6	895.10	5.41	889.69	5.83	889.27	6.33	888.77	6.68	888.42	6.65	888.45	6.38	888.72	0.27
B3A-1B	15,775.35	18,091.00	880.99-870.99	894.99	7.20	887.79	7.35	887.64	7.54	887.45	7.87	887.12	5.28	889.71	5.53	889.46	0.25
B3A-2A	15,777.50	18,076.95	889.88-883.88	894.88	5.76	889.12	7.29	887.59	7.54	887.34	7.01	887.87	7.40	887.48	DRY	<886.80	0.68
B3A-2B	15,782.62	18,081.71	879.95-876.95	894.95	7.55	887.40	7.60	887.35	8.16	886.79	8.29	886.66	7.81	887.14	7.75	887.20	0.06
B3A-3	15,792.25	18,057.35	887.55-883.55	891.55	6.12	885.43	DRY	<884.54	DRY	<884.54	DRY	<884.54	DRY	<884.54	DRY	<884.54	0.00
B4A-1A	16,723.24	18,919.21	889.88-885.88	893.88	6.09	887.79	6.31	887.57	DRY	<886.64	DRY	<886.64	DRY	<886.64	DRY	<886.64	0.00
B4A-1B	16,719.44	18,914.57	879.04-876.04	894.04	7.97	886.07	7.97	886.07	8.21	885.83	8.38	885.66	8.40	885.64	8.41	885.63	0.01
B4A-2	16,736.01	18,909.14	888.42-884.42	893.42	6.61	886.81	7.46	885.96	DRY	<885.41	DRY	<885.41	DRY	<885.41	DRY	<885.41	0.00
B4A-3	16,748.06	18,899.66	882.86-878.66	890.86	10.24	880.62	10.71	880.15	DRY	<879.68	DRY	<879.68	10.59	880.27	DRY	<879.68	0.59
B5-1A	18,798.33	22,855.46	889.19-886.19	895.19	8.36	886.83	DRY	<885.85	DRY	<885.85	DRY	<885.85	DRY	<885.85	DRY	<885.85	0.00
B5-1B	18,795.38	22,857.74	881.95-874.95	894.95	8.16	886.79	8.47	886.48	8.87	886.08	8.97	885.98	8.72	886.23	8.36	886.59	0.36
B5-2	18,805.00	22,849.89	888.81-885.81	894.81	DRY	<885.16	DRY	<885.16	DRY	<885.16	DRY	<885.16	DRY	<885.16	DRY	<885.16	0.00
B5-3	18,818.39	22,838.28	881.57-879.07	886.07	2.32	883.75	2.50	883.57	2.83	883.24	3.27	882.80	3.44	882.63	3.15	882.92	0.29
POOL	N/A	N/A	N/A	N/A	N/A	892.22	N/A	892.24	N/A	892.12	N/A	892.03	N/A	891.94	N/A	892.14	0.20

NOTE
1) Less than symbol (<) indicates piezometer tip elevation

Table 4-1
SUMMARY OF TRIAXIAL TEST DATA - EMBANKMENT FILL
EFFECTIVE AND TOTAL STRESS PARAMETERS
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736-730-96-034

	Boring No.	Sample No.	Cell Pressure (tsf)	Strain at Failure (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	σ_1 ' (tsf)	σ_3 ' (tsf)	Maximum Shear Stress (tsf)	Center (Effective)	σ_1 (tsf)	σ_3 (tsf)	Center (Total)
Paul C. Rizzo Ass[illegible]es, Inc	B2A-2	ST-3	0.25	18.8	0.91		1.18	0.27	0.46	0.73	1.16	0.25	0.71
	B2A-2	ST-3	0.31	20	1.37		1.75	0.39	0.68	1.07	1.68	0.31	1.00
	B2A-2	ST-3	0.63	20	1.28		1.56	0.28	0.64	0.92	1.91	0.63	1.27
Dodson-Lindblom Associates, Inc	3	P1-S1	4.50	20	1.8	-0.45	6.75	4.95	0.90	5.85	6.3	4.50	5.40
	3	P1-S2	4.00	14.5	1.68	-0.33	6.01	4.33	0.84	5.17	5.68	4.00	4.84
	5	P1-S1	4.00	20	1.35	-0.2	5.55	4.20	0.68	4.88	5.35	4.00	4.68
	5	P1-S2	4.50	17.5	2.28	-0.15	6.93	4.65	1.14	5.79	6.78	4.50	5.64
	5	P1-S3	4.50	20	2.87	-0.2	7.57	4.70	1.44	6.14	7.37	4.50	5.94
	8	P1-S1	4.00	18.5	1.46	-0.35	5.81	4.35	0.73	5.08	5.46	4.00	4.73
	8	P1-S2	4.50	20	3.8	-0.7	9.00	5.20	1.90	7.10	8.3	4.50	6.40
	8	P1-S3	4.50	20	3.95	-0.6	9.05	5.10	1.98	7.08	8.45	4.50	6.48

σ_1' - Major Principal Stress (effective)
σ_3' - Minor Principal Stress (effective)
σ_1 - Major Principal Stress (total)
σ_3 - Minor Principal Stress (total)
tsf - Tons per Square Foot
% - Percent

Table 4-2
SUMMARY OF TRIAXIAL TEST DATA - FOUNDATION TILL
EFFECTIVE AND TOTAL STRESS PARAMETERS
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736-730-96-034

	Boring No	Sample No.	Cell Pressure (tsf)	Strain at Failure (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	σ_1' (tsf)	σ_3' (tsf)	Maximum Shear Stress (tsf)	Center (Effective)	σ_1 (tsf)	σ_3 (tsf)	Center (Total)
Paul C. Rizzo Associates, Inc.	B4A-2	ST-5	0.44	20	1.36		1.76	0.40	0.68	1.08	1.8	0.44	1.12
	B4A-2	ST-5	0.55	20	1.6		1.85	0.25	0.80	1.05	2.15	0.55	1.35
	B4A-2	ST-5	1.1	20	2.7		3.46	0.75	1.36	2.11	3.8	1.1	2.45
	B5A-3	ST-3	0.26	20	1.88		2.58	0.70	0.94	1.64	2.14	0.26	1.20
	B5A-3	ST-3	0.32	20	1.93		2.64	0.72	0.96	1.68	2.25	0.32	1.29
	B5A-3	ST-3	0.65	20	3.02		4.73	1.26	1.74	3.00	3.67	0.65	2.16
Dodson-Lindblom Associates, Inc.	3	P3-S1	4.00	20	1.85	-0.15	6.00	4.15	0.93	5.08	5.85	4.00	4.93
	3	P3-S2	4.50	20	2.7	0.05	7.15	4.45	1.35	5.80	7.2	4.50	5.85
	3	P3-S3	4.00	20	3.04	0.5	6.54	3.50	1.52	5.02	7.04	4.00	5.52
	3	P4-S1	4.00	19.5	0.77	0.5	4.27	3.50	0.39	3.89	4.77	4.00	4.39
	3	P4-S2	4.50	21	1.45	0.75	5.20	3.75	0.73	4.48	5.95	4.50	5.23
	3	P4-S3	4.00	20	1.77	1.15	4.62	2.85	0.89	3.74	5.77	4.00	4.89
	5	P3-S1	5.00	18.8	2.48	-0.15	7.63	5.15	1.24	6.39	7.48	5.00	6.24
	5	P3-S2	5.00	18.5	2.55	0.3	7.25	4.70	1.28	5.98	7.55	5.00	6.28
	5	P3-S3	5.00	19.3	2.6	0.8	6.80	4.20	1.30	5.50	7.6	5.00	6.30
	8	P2-S1	5.00	19.3	1.33	0.4	5.93	4.60	0.67	5.27	6.33	5.00	5.67
	8	P2-S2	5.00	19.3	1.33	0.75	5.58	4.25	0.67	4.92	6.33	5.00	5.67
	8	P2-S3	5.00	19.8	1.38	0.85	5.53	4.15	0.69	4.84	6.38	5.00	5.69

σ_1' - Major Principal Stress (effective)
σ_3' - Minor Principal Stress (effective)
σ_1 - Major Principal Stress (total)
σ_3 - Minor Principal Stress (total)
tsf - Tons per Square Foot
% - Percent

Table 4-3
SOIL STRENGTH PARAMETERS
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736-730-96-034

SOIL	C' (tsf)	ϕ'	C (tsf)	ϕ
Fill	0.16	7.3°	0.16	8.0°
Till	0.70	5.4°	0.65	5.8°

C' - Cohesion (effective)
ϕ' - Angle of Internal Friction (effective)
C - Cohesion (total)
ϕ - Angle of Internal Friction (total)
tsf - Tons per Square Foot
° - Degrees

Table 4-4
SUMMARY OF LOADING CONDITIONS FOR STABILITY ANALYSIS
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736-730-96-034

Section No.	Case No.	Stress State [1]	Phreatic Surface	Strength Parameters	Tailwater Level	Factor of Safety (FS)	Remarks
1A	1-B	"Before"	As measured in 1996	Effective Stress	None	5.23	Best Assessment of Current Conditions
	2-B	"Before"	As measured in 1996	Total Stress	None	5.28	
	3-B	"Before"	As measured in 1996	Cohesionless Embankment Total Stress for Foundation	None	3.78	
	1-A	"After" (Crest Raised)	Raised for PMF	Effective Stress	None	4.55	Best Assessment of Future Conditions under PMF
	2-A	"After" (Crest Raised)	Raised for PMF	Total Stress	None	4.60	
	3-A	"After" (Crest Raised)	Raised for PMF	Cohesionless Embankment Total Stress for Foundation	None	3.94	
2A	1-B	"Before"	As measured in 1996	Effective Stress	None	4.83	Best Assessment of Current Conditions
	2-B	"Before"	As measured in 1996	Total Stress	None	4.90	
	3-B	"Before"	As measured in 1996	Cohesionless Embankment Total Stress for Foundation	None	3.01	
	1-A	"After" (Crest Raised)	Raised for PMF	Effective Stress	None	4.02	Best Assessment of Future Conditions under PMF
	2-A	"After" (Crest Raised)	Raised for PMF	Total Stress	None	4.07	
	3-A	"After" (Crest Raised)	Raised for PMF	Cohesionless Embankment Total Stress for Foundation	None	2.94	

1 - "Before" - Lake at normal pool elevation - 892.25 ft.

"After" - Embankment raised to accommodate PMF at elevation - 897.0 ft

Table 4-4 (cont.)
SUMMARY OF LOADING CONDITIONS FOR STABILITY ANALYSIS
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736-730-96-034

Section No.	Case No.	Stress State [1]	Phreatic Surface	Strength Parameters	Tailwater Level	Factor of Safety (FS)	Remarks
3A	1-B	"Before"	As measured in 1996	Effective Stress	None	3.09	Best Assessment of Current Conditions
	2-B	"Before"	As measured in 1996	Total Stress	None	3.11	
	3-B	"Before"	As measured in 1996	Cohesionless Embankment Total Stress for Foundation	None	2.91	
	4-B	"Before" with Earthquake	As measured in 1996	Total Stress	None	2.27	Best Assessment Under Earthquake
	5-B	"Before" with Tailwater	As measured in 1996	Effective Stress	Elev. 890.0	3.77	Best Assessment of Current Conditions with Downstream Flooding
	1-A	"After" (Crest Raised)	Raised for PMF	Effective Stress	None	2.45	Best Assessment of Future Conditions under PMF
	2-A	"After" (Crest Raised)	Raised for PMF	Total Stress	None	2.48	
	3-A	"After" (Crest Raised)	Raised for PMF	Cohesionless Embankment Total Stress for Foundation	None	2.71	
	4-A	"After" (Crest Raised) with Earthquake	Raised for PMF	Total Stress	None	1.89	Highly Unlikely Event Combination
	5-A	"After" (Crest Raised) with Tailwater	Raised for PMF	Effective Stress	Elev. 890.0	2.86	Best Assessment of Future Conditions with Downstream Flooding

1 - "Before" - Lake at normal pool elevation - 892.25 ft.

"After" - Embankment raised to accommodate PMF at elevation - 897.0 ft

Table 4-4 (cont.)
SUMMARY OF LOADING CONDITIONS FOR STABILITY ANALYSIS
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736-730-96-034

Section No.	Case No.	Stress State[1]	Phreatic Surface	Strength Parameters	Tailwater Level	Factor of Safety (FS)	Remarks
3A (with structure)	6-B	"Before"	As measured in 1996	Effective Stress	None	2.72	Best Assessment of Current Conditions
	7-B	"Before"	As measured in 1996	Total Stress	None	2.74	
	8-B	"Before"	As measured in 1996	Cohesionless Embankment Total Stress for Foundation	None	2.94	
	9-B	"Before" with Earthquake	As measured in 1996	Total Stress	None	2.24	Best Assessment Under Earthquake
	10-B	"Before" with Tailwater	As measured in 1996	Effective Stress	Elev. 890.0	2.40	Best Assessment of Current Conditions with Downstream Flooding
	6-A	"After" (Crest Raised)	Raised for PMF	Effective Stress	None	2.31	Best Assessment of Future Conditions under PMF
	7-A	"After" (Crest Raised)	Raised for PMF	Total Stress	None	2.24	
	8-A	"After" (Crest Raised)	Raised for PMF	Cohesionless Embankment Total Stress for Foundation	None	2.56	
	9-A	"After" (Crest Raised) with Earthquake	Raised for PMF	Total Stress	None	1.73	Highly Unlikely Event Combination
	10-A	"After" (Crest Raised) with Tailwater	Raised for PMF	Effective Stress	Elev. 890.0	1.89	Best Assessment of Future Conditions with Downstream Flooding

1 - "Before" - Lake at normal level elevation - 892.25 ft
"After" - Embankment raised to accommodate PMF at elevation - 897.0 ft

Table 4-4 (cont.)
SUMMARY OF LOADING CONDITIONS FOR STABILITY ANALYSIS
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736-730-96-034

Section No.	Case No.	Stress State [1]	Phreatic Surface	Strength Parameters	Tailwater Level	Factor of Safety (FS)	Remarks
4A	1-B	"Before"	As measured in 1996	Effective Stress	None	3.56	Best Assessment of Current Conditions
	2-B	"Before"	As measured in 1996	Total Stress	None	3.65	
	3-B	"Before"	As measured in 1996	Cohesionless Embankment Total Stress for Foundation	None	3.00	
	1-A	"After" (Crest Raised)	Raised for PMF	Effective Stress	None	2.41	Best Assessment of Future Conditions under PMF
	2-A	"After" (Crest Raised)	Raised for PMF	Total Stress	None	2.46	
	3-A	"After" (Crest Raised)	Raised for PMF	Cohesionless Embankment Total Stress for Foundation	None	3.05	
5A	1-B	"Before"	As measured in 1996	Effective Stress	None	7.17	Best Assessment of Current Conditions
	2-B	"Before"	As measured in 1996	Total Stress	None	7.23	
	3-B	"Before"	As measured in 1996	Cohesionless Embankment Total Stress for Foundation	None	4.09	
	1-A	"After" (Crest Raised)	Raised for PMF	Effective Stress	None	4.43	Best Assessment of Future Conditions under PMF
	2-A	"After" (Crest Raised)	Raised for PMF	Total Stress	None	4.47	
	3-A	"After" (Crest Raised)	Raised for PMF	Cohesionless Embankment Total Stress for Foundation	None	2.66	

1 - "Before" - Lake at normal pool elevation - 892.25 ft.

"After" - Embankment raised to accommodate PMF at elevation - 897.0 ft

Table 4-5
SUMMARY OF LOADING CONDITIONS FOR STABILITY ANALYSIS - DLA
BUCKEYE LAKE DAM STABILITY STUDY
DNR 736-730-96-034

Section No.	Case No.	Stress State [1]	Phreatic Surface	Strength Parameters	Tailwater Level	Factor of Safety (FS)	Factor of Safety (FS) - DLA	Remarks
2	1-B	"Before"	As measured in 1987	Effective Stress	None	11.6	1.49	Best Assessment of Current Conditions
	2-B	"Before"	As measured in 1987	Total Stress	None	10.86		
	3-B	"Before"	As measured in 1987	Cohesionless Embankment Effective Stress for Foundation	None	11.20		
	1-A	"After" (Crest Raised)	Raised for PMF	Effective Stress	Elev. 890.0	5.85	1.03	Best Assessment of Future Conditions under PMF with Downstream Flooding
	2-A	"After" (Crest Raised)	Raised for PMF	Total Stress	Elev. 890.0	5.58		
	3-A	"After" (Crest Raised)	Raised for PMF	Cohesionless Embankment Effective Stress for Foundation	Elev. 890.0	4.99		

1 - "Before" - Lake at normal pool elevation - 892.25 ft.
"After" - Embankment raised to accommodate PMF at elevation - 897.0 ft.

FIGURES

95-1590-T1
PLOT: 1=1

Department of Natural Resources

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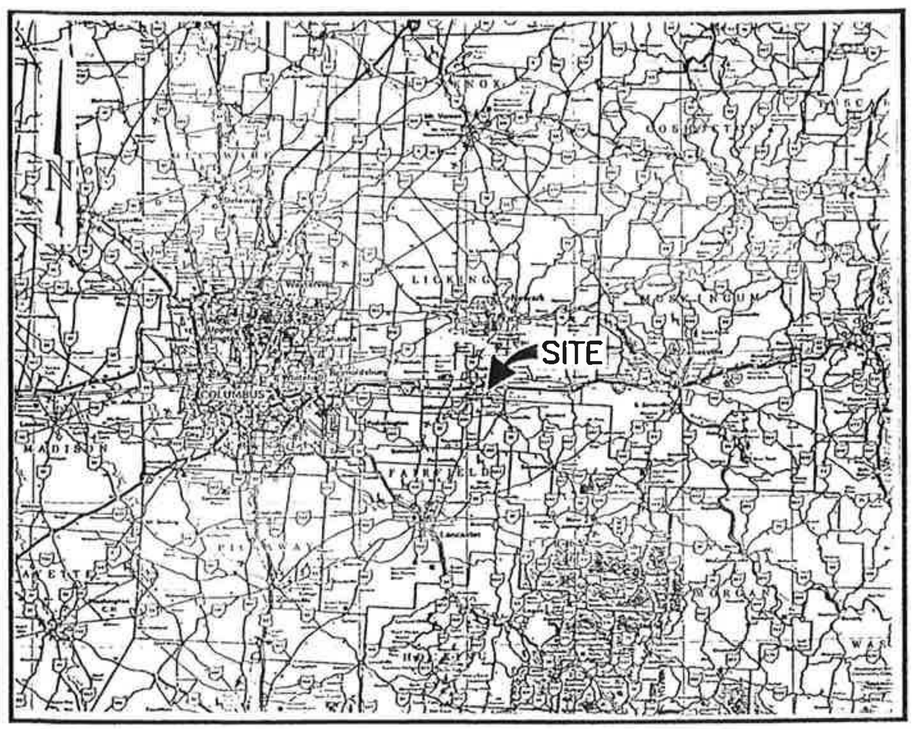
DIVISION OF ENGINEERING

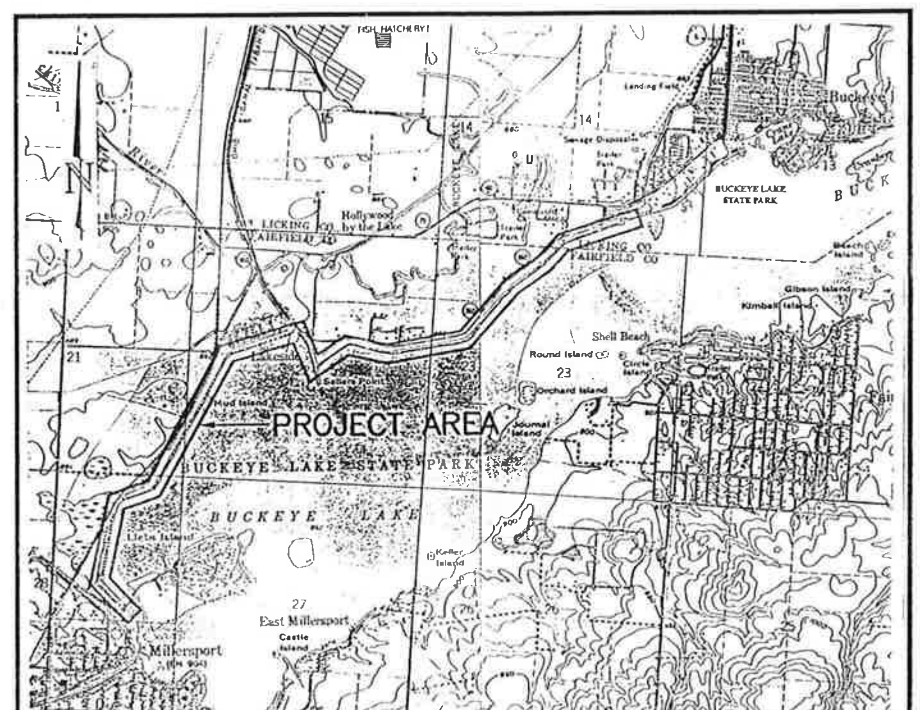
BUCKEYE LAKE STATE PARK

DAM STABILITY STUDY

FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO



LOCATION MAP
SCALE
5 0 5 MILES



VICINITY MAP
SCALE
2000 0 2000 FEET

APPROVED

CHIEF, Division of PARKS & RECREATION

DATE

CHIEF, Division of ENGINEERING

DATE

SHEET INDEX

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Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

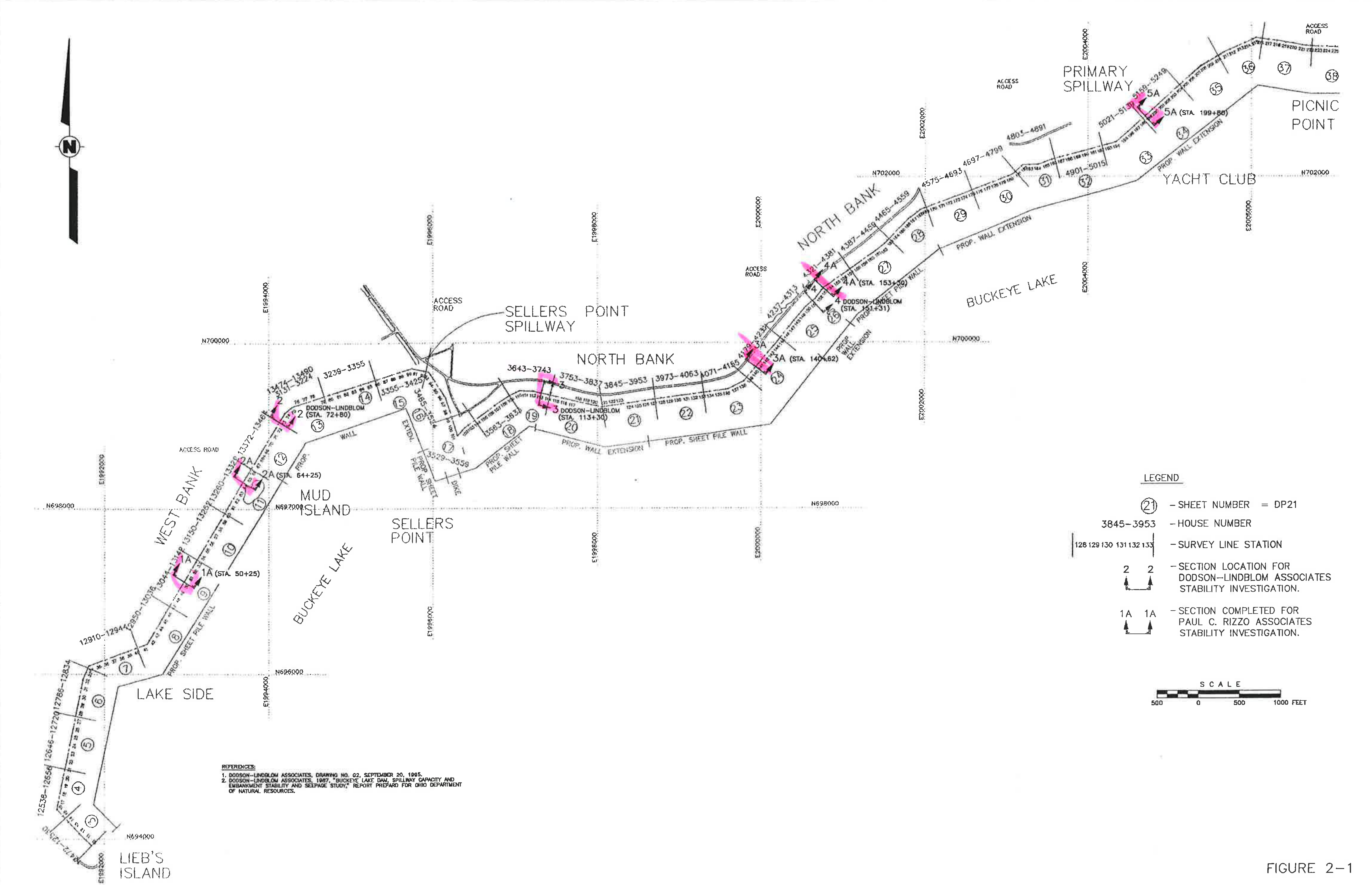
STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

TITLE SHEET

DESIGNED BY:	
DRAWN BY.	D. J. DOBIES
CHECKED BY:	[signature]
APPROVED BY:	[signature]
JOB NUMBER:	DNR 736 730-96-034
SCALE:	AS SHOWN
DATE:	10-31-96
REVISED:	

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTY, OHIO

95-1590-E7A
PLOT 1=500



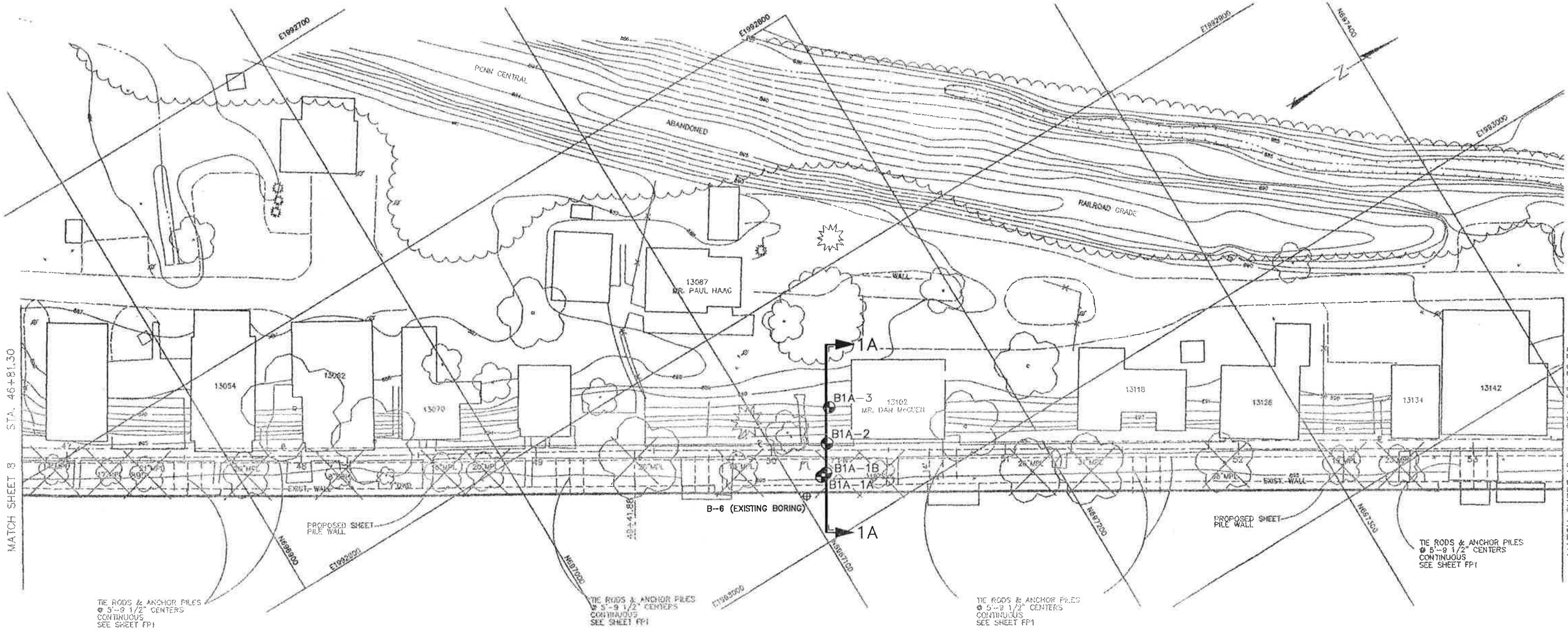
REFERENCES:

1. DODSON-LINDBLOM ASSOCIATES, DRAWING NO. 02, SEPTEMBER 20, 1995.
2. DODSON-LINDBLOM ASSOCIATES, 1987, "BUCKEYE LAKE DAM, SPILLWAY CAPACITY AND EMBANKMENT STABILITY AND SEEPAGE STUDY," REPORT PREPARD FOR OHIO DEPARTMENT OF NATURAL RESOURCES.

FIGURE 2-1

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-26-96 REVISED:	PLAN SHEET INDEX	2/29

95-1590-E25
PLOT 1-20



LEGEND:

B1A-2 — PIEZOMETER TEST BORING BY PAUL C. RIZZO ASSOCIATES

B-6 — EXISTING BORING

1A — 1A — PLAN LOCATION OF DAM CROSS SECTION PRESENTED ON FIGURE 2-3

SCALE: 20 0 20 40 FEET

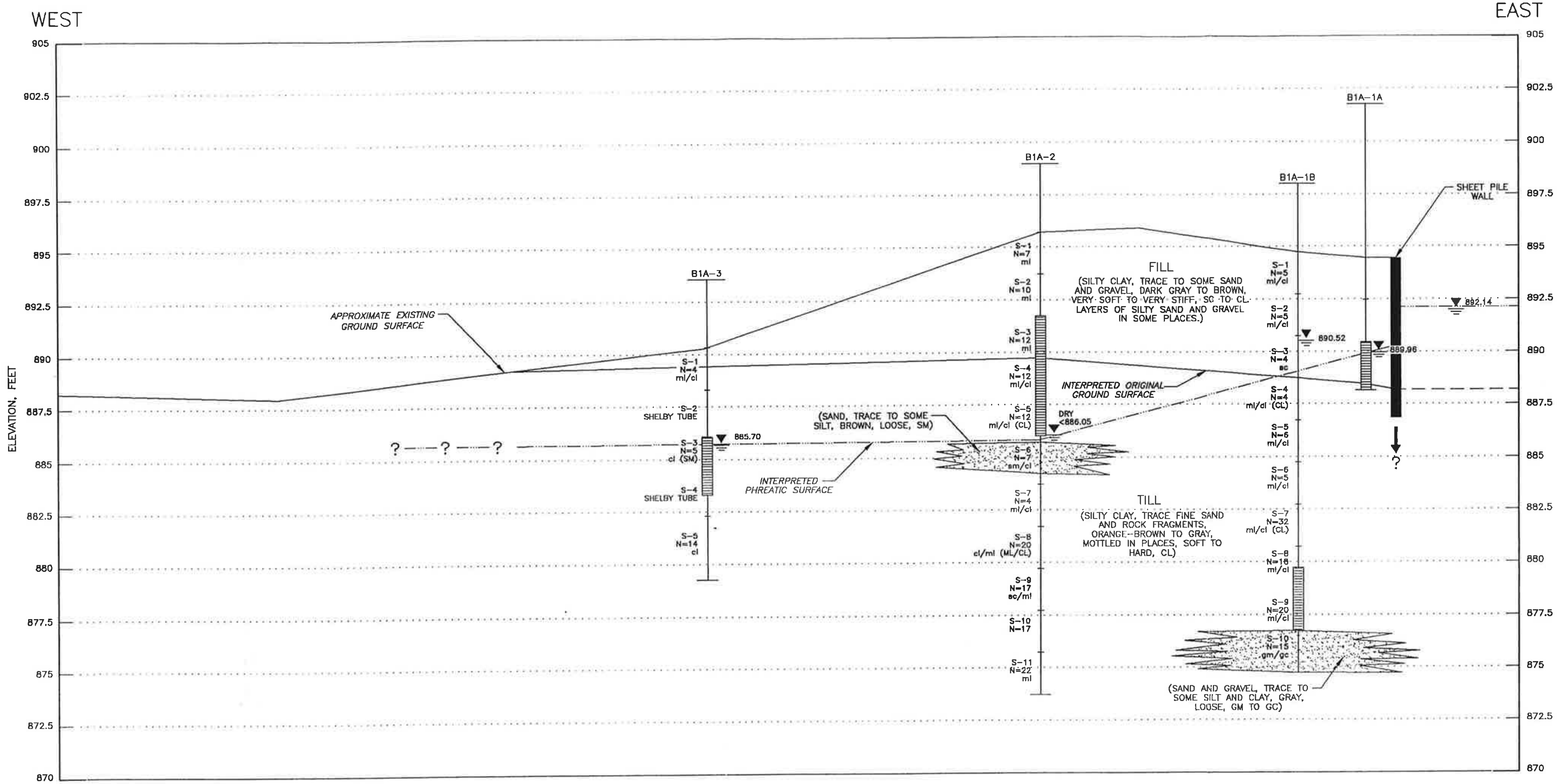
REFERENCES:
1. DODSON-LINDBLOM ASSOCIATES, DRAWING NO. DP9, SEPTEMBER 20, 1995.
2. DODSON-LINDBLOM ASSOCIATES, 1987, "BUCKEYE LAKE DAM, SPILLWAY CAPACITY AND EMBANKMENT STABILITY AND SEEPAGE STUDY," REPORT PREPARED FOR OHIO DEPARTMENT OF NATURAL RESOURCES.

FIGURE 2-2

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-28-96 REVISED:	PLAN AND LOCATION OF SECTION 1A

3/29

95-1590-E16
PLOT 1=1



SECTION 1A
STA. 50+25

SCALE
2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 2-3

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

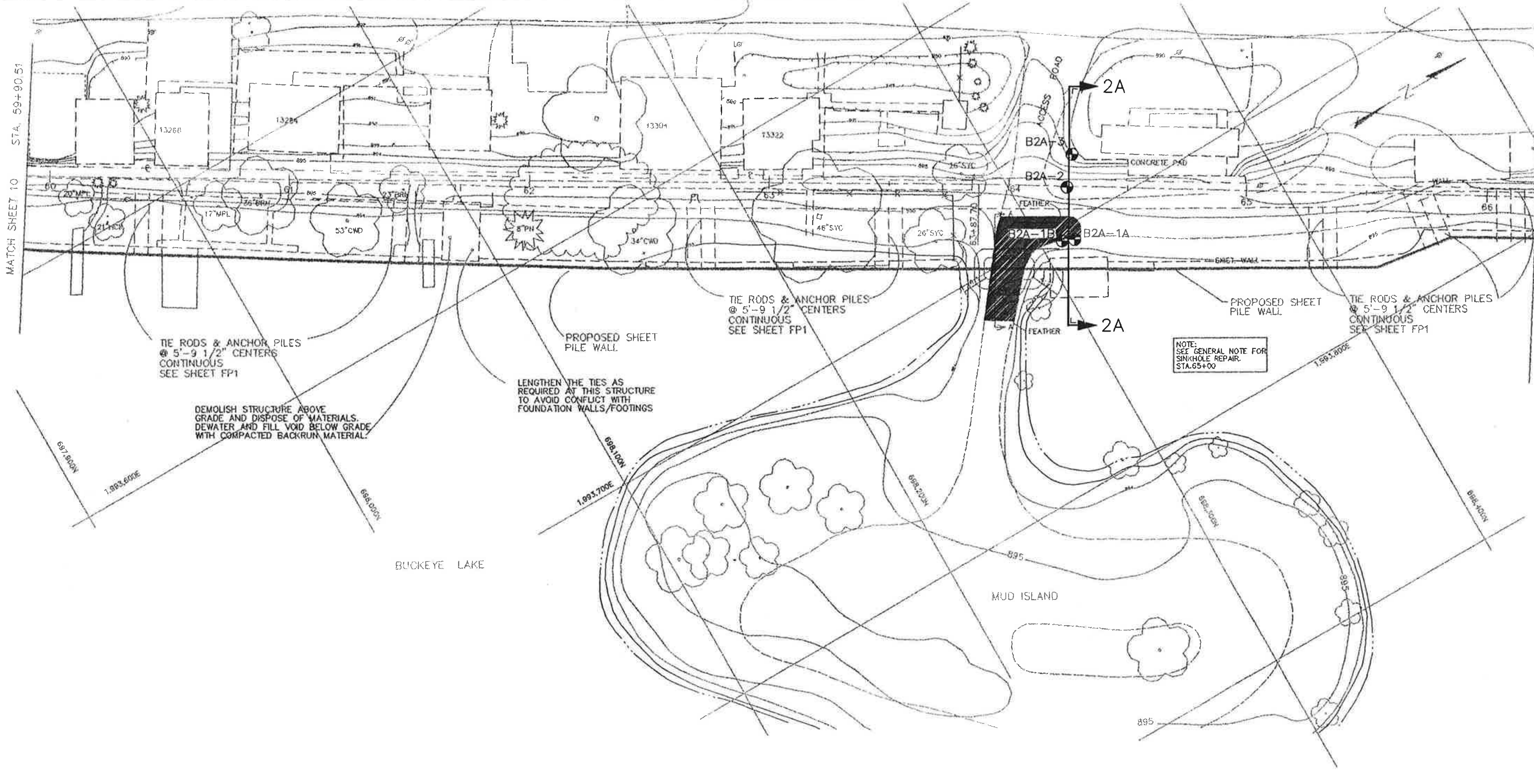
DESIGNED BY:
DRAWN BY: D. J. DOBIES
CHECKED BY:
APPROVED BY:

JOB NUMBER: DNR 736 730-96-034
SCALE: AS SHOWN
DATE: 6-25-96
REVISED:

DAM CROSS SECTION 1A

4/29

95-1590-E23
PLOT 1=20



LEGEND:

B2A-2 — PIEZOMETER TEST BORING BY PAUL C. RIZZO ASSOCIATES

2A 2A — PLAN LOCATION OF DAM CROSS SECTION PRESENTED ON FIGURE 2-5

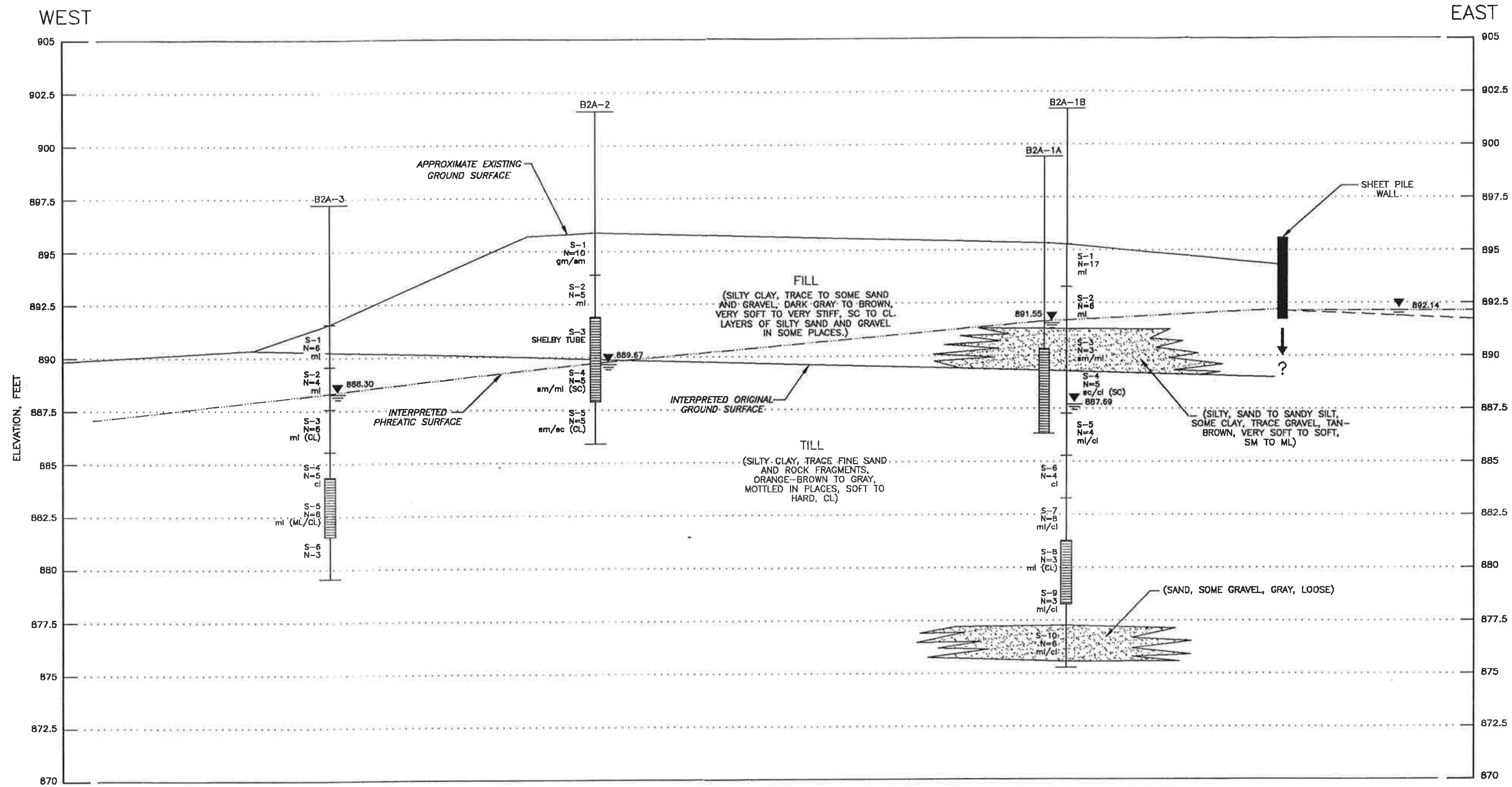
SCALE
20 0 20 40 FEET

REFERENCES:
1. DODSON-LINDBLOM ASSOCIATES, DRAWING NO. DP11, SEPTEMBER 20, 1995.
2. DODSON-LINDBLOM ASSOCIATES, 1987, "BUCKEYE LAKE DAM, SPILLWAY CAPACITY AND EMBANKMENT STABILITY AND SEEPAGE STUDY," REPORT PREPARD FOR OHIO DEPARTMENT OF NATURAL RESOURCES.

FIGURE 2-4

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 8-28-96 REVISED:	PLAN AND LOCATION OF SECTION 2A

95-1590-E17
PLOT 1=1



SECTION 2A
STA. 64+25

SCALE
2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 2-5

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

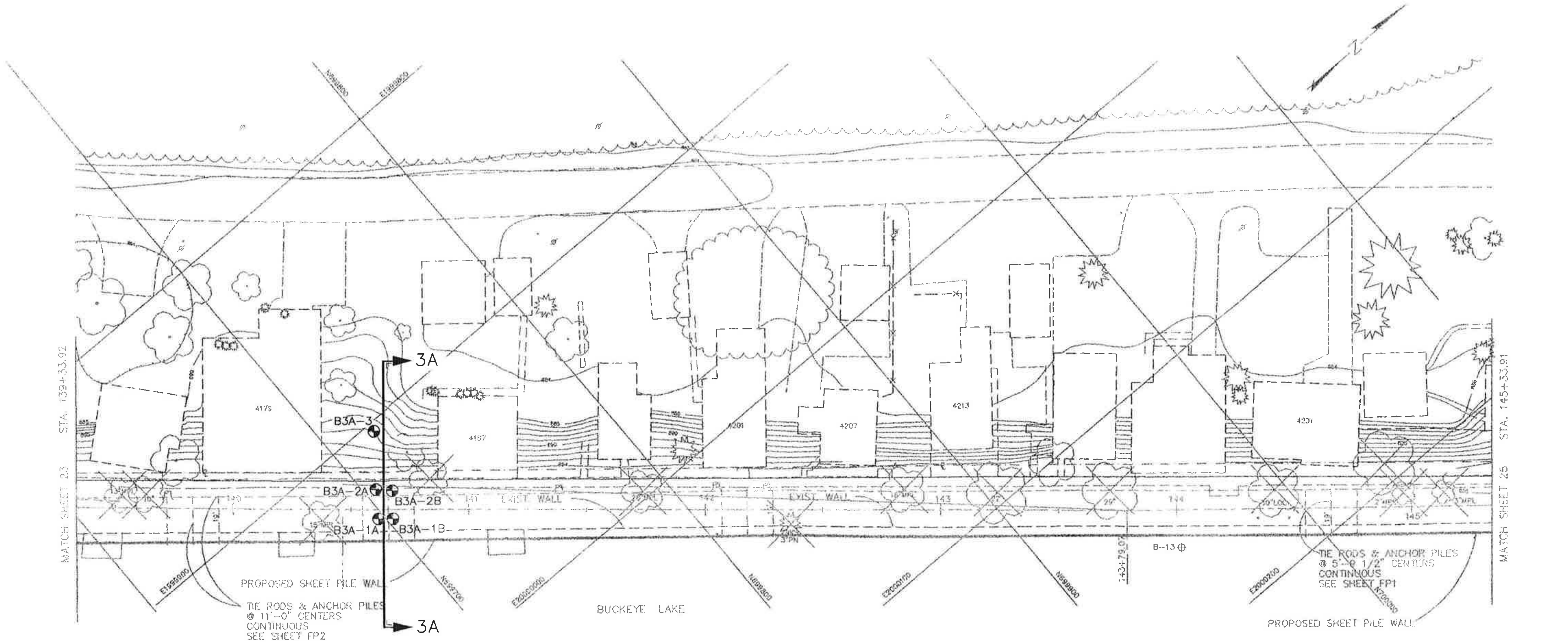
DESIGNED BY:
DRAWN BY: D. J. DOBIES
CHECKED BY:
APPROVED BY:

JOB NUMBER: DNR 736 730-96-034
SCALE: AS SHOWN
DATE: 8-26-96
REVISED:

DAM CROSS SECTION 2A

6/29

95-1590-E24
PLOT 1=20



LEGEND:

B3A-2A ⊕ PIEZOMETER TEST BORING BY PAUL C. RIZZO ASSOCIATES

B-13 ⊕ EXISTING BORING

3A 3A PLAN LOCATION OF DAM CROSS SECTION PRESENTED ON FIGURE 2-7

REFERENCES:
1. DODSON-LINDBLOM ASSOCIATES, DRAWING NO. DP24, SEPTEMBER 20, 1995.
2. DODSON-LINDBLOM ASSOCIATES, 1987, "BUCKEYE LAKE DAM, SPILLWAY CAPACITY AND EMBANKMENT STABILITY AND SEEPAGE STUDY," REPORT PREPARD FOR OHIO DEPARTMENT OF NATURAL RESOURCES.

SCALE
20 0 20 40 FEET

FIGURE 2-6

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

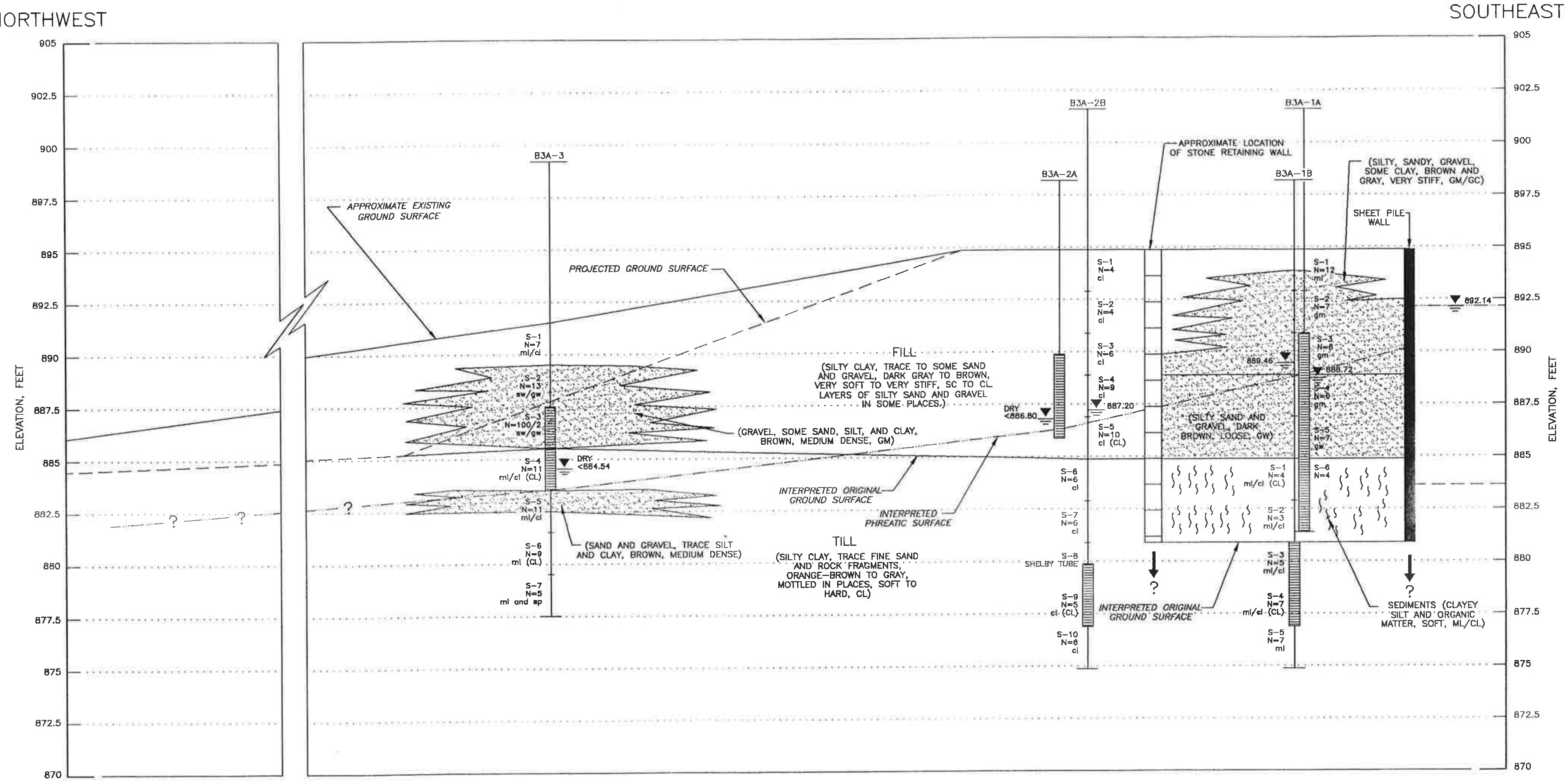
STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

DESIGNED BY:	JOB NUMBER: DNR 736 730-96-034
DRAWN BY: D. J. DOBIES	SCALE: AS SHOWN
CHECKED BY:	DATE: 8-28-96
APPROVED BY:	REVISED:

PLAN AND LOCATION OF SECTION 3A

7/29



SECTION 3A

STA. 140+62

SCALE

2.5 0 2.5 5 FEET

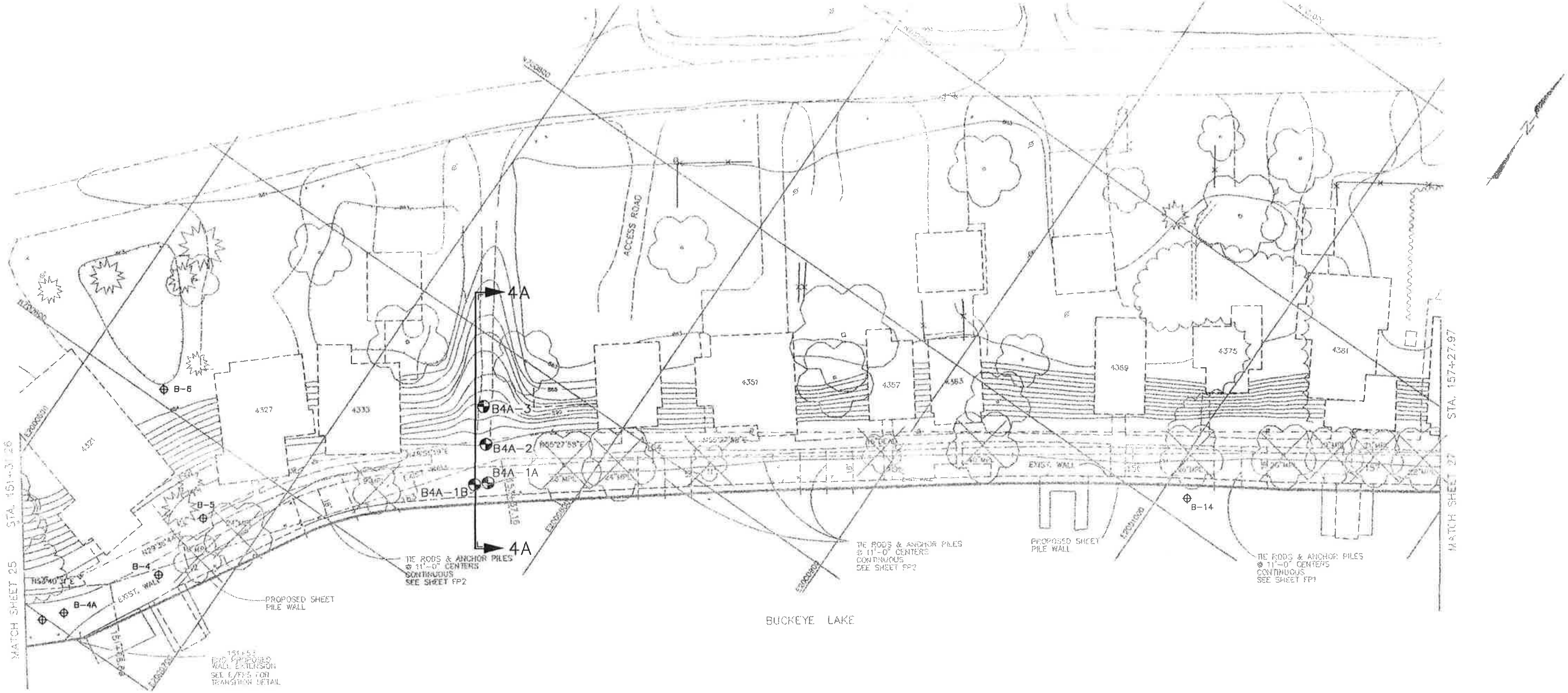
LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▽	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▥	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 2-7

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-26-96 REVISED:	DAM CROSS SECTION 3A

95-1590-E21
PLOT 1=20



LEGEND:

B4A-2	PIEZOMETER TEST BORING BY PAUL C. RIZZO ASSOCIATES
B-6	EXISTING BORING
4A 4A	PLAN LOCATION OF DAM CROSS SECTION PRESENTED ON FIGURE 2-9

SCALE
20 0 20 40 FEET

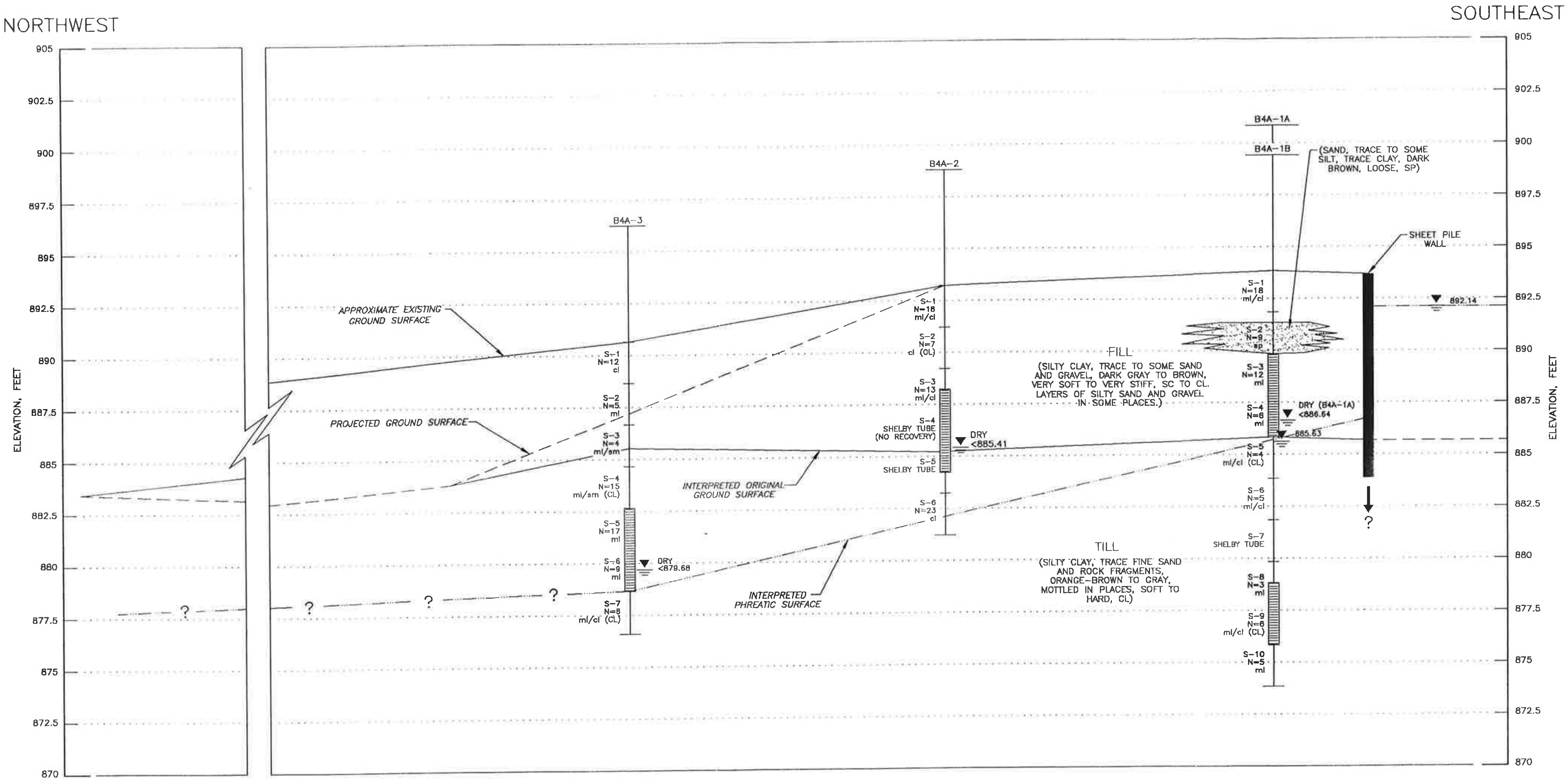
REFERENCES:

DODSON-LINDBLOM ASSOCIATES, DRAWING NO. DP26, SEPTEMBER 20, 1995.
DODSON-LINDBLOM ASSOCIATES, 1987, "BUCKEYE LAKE DAM, SPILLWAY CAPACITY AND EMBANKMENT STABILITY AND SEEPAGE STUDY," REPORT PREPARD FOR OHIO DEPARTMENT OF NATURAL RESOURCES.

FIGURE 2-8

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 738 730-96-034 SCALE: AS SHOWN DATE: 6-28-96 REVISED:	PLAN AND LOCATION OF SECTION 4A

95-1590-E19 PLOT 1=1



SECTION 4A

STA. 153+30

LEGEND:

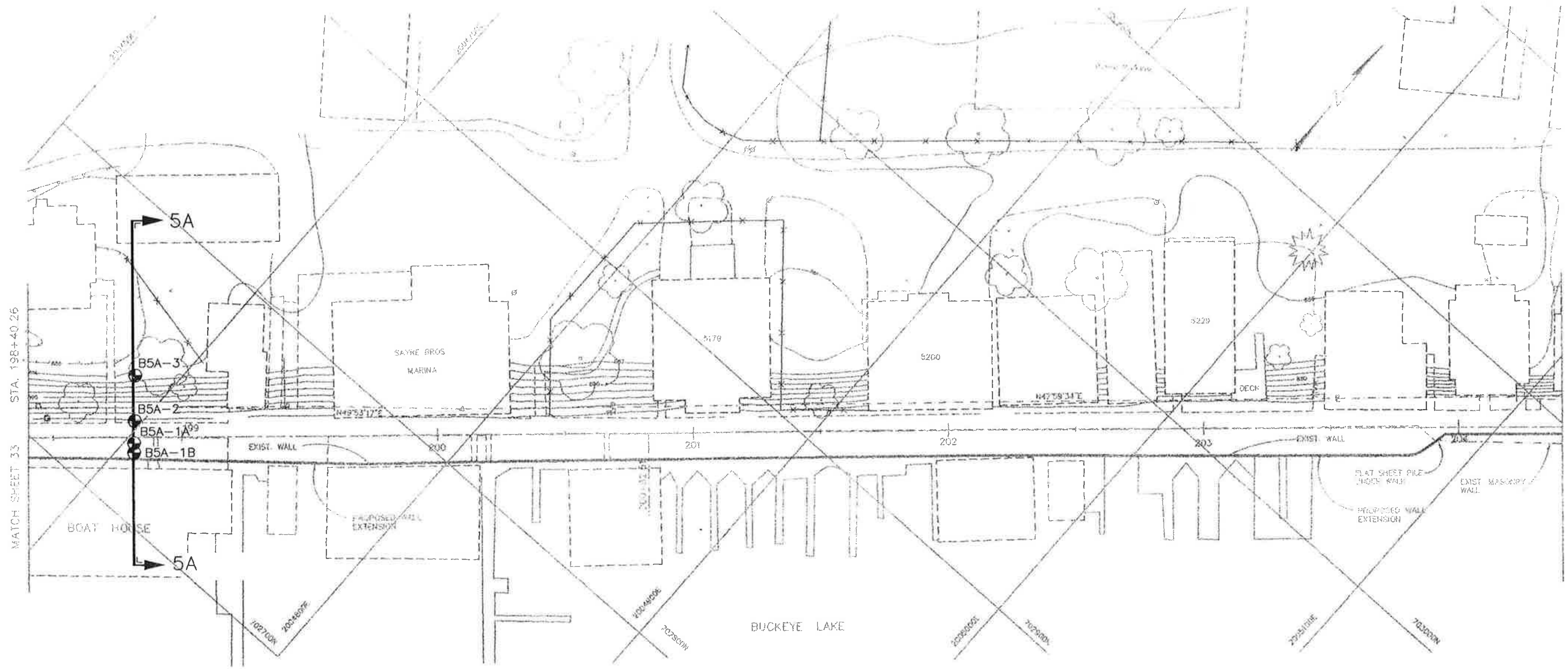
- S-1 SAMPLE NO.
- N=5 STANDARD PENETRATION TEST "N"
- ml/cl FIELD DETERMINED U.S.C.S. CLASSIFICATION
- (CL) LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
- ▼ STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
- PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

SCALE
2.5 0 2.5 5 FEET

FIGURE 2-9

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-26-96 REVISED	DAM CROSS SECTION 4A	10/29

95-1590-E22
PLOT 1=20



LEGEND:

B5A-2 — PIEZOMETER TEST BORING BY PAUL C. RIZZO ASSOCIATES

5A 5A — PLAN LOCATION OF DAM CROSS SECTION PRESENTED ON FIGURE 2-11

SCALE
20 0 20 40 FEET

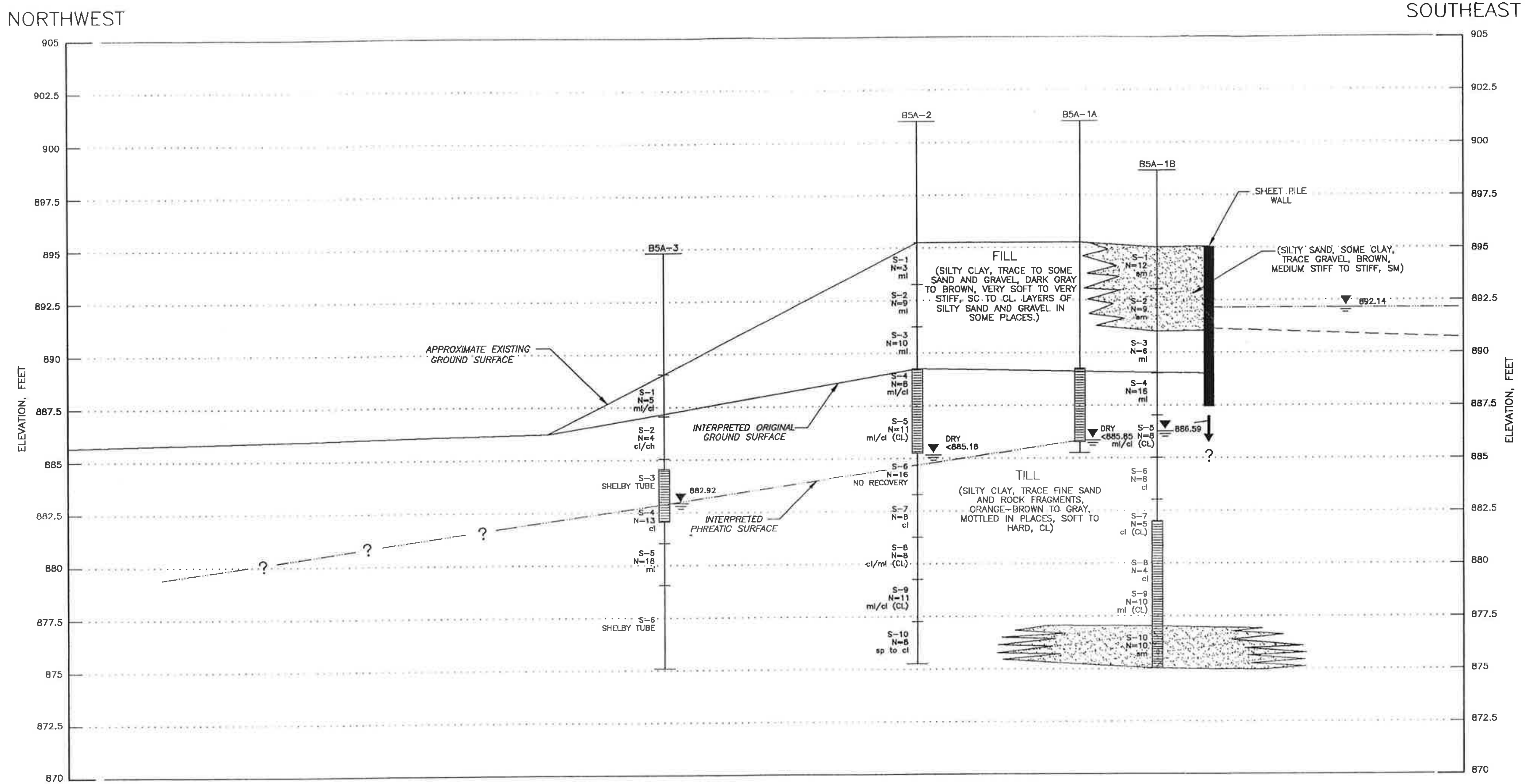
FIGURE 2-10

REFERENCES:

1. DODSON-LINDBLOM ASSOCIATES, DRAWING NO. DP34, SEPTEMBER 13, 1995.
2. DODSON-LINDBLOM ASSOCIATES, 1987, "BUCKEYE LAKE DAM, SPILLWAY CAPACITY AND EMBANKMENT STABILITY AND SEEPAGE STUDY," REPORT PREPARD FOR OHIO DEPARTMENT OF NATURAL RESOURCES.

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DORIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-28-96 REVISED	PLAN AND LOCATION OF SECTION 5A

95-1590-E20
PLOT 1=1



SECTION 5A

STA. 199+80

SCALE
2.5 0 2.5 5 FEET

LEGEND:

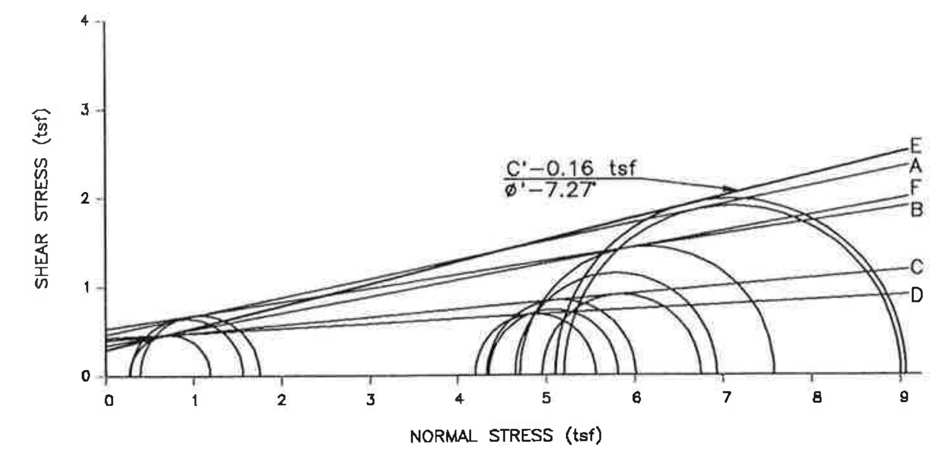
S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▥	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 2-11

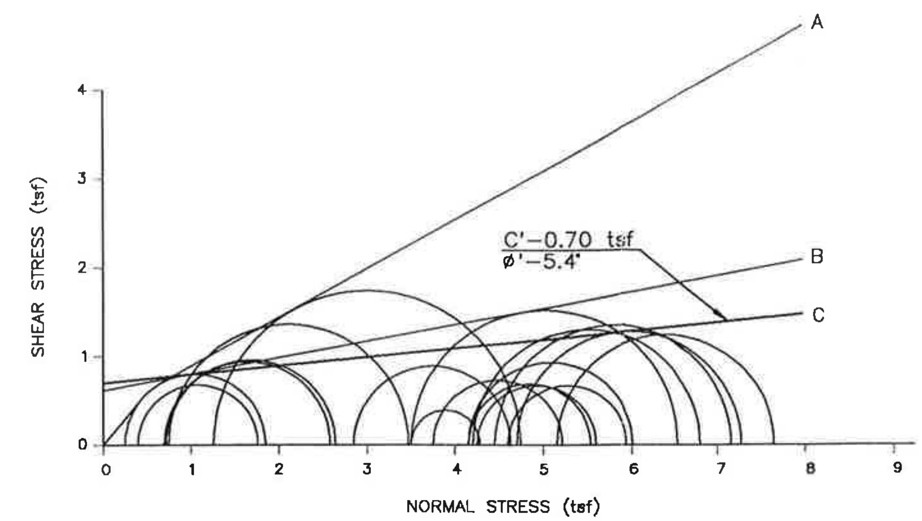
Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-26-96 REVISED:	DAM CROSS SECTION 5A

12/29

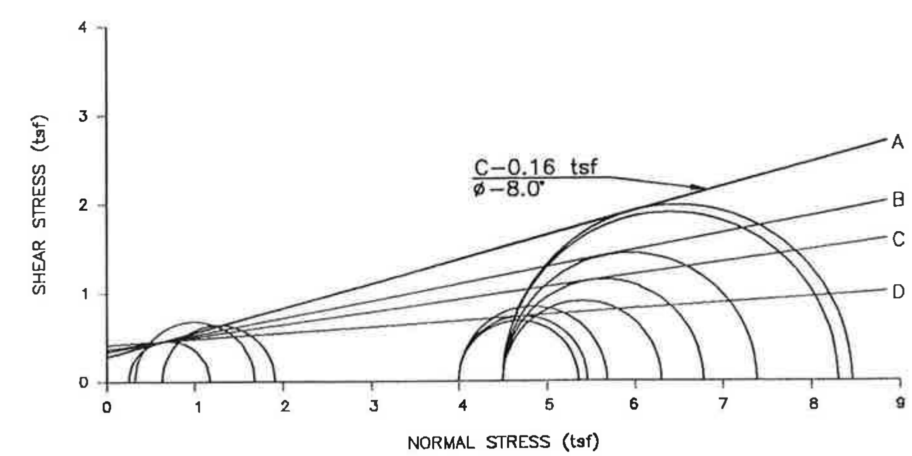
95-1590-E26
PLOT: 1=1



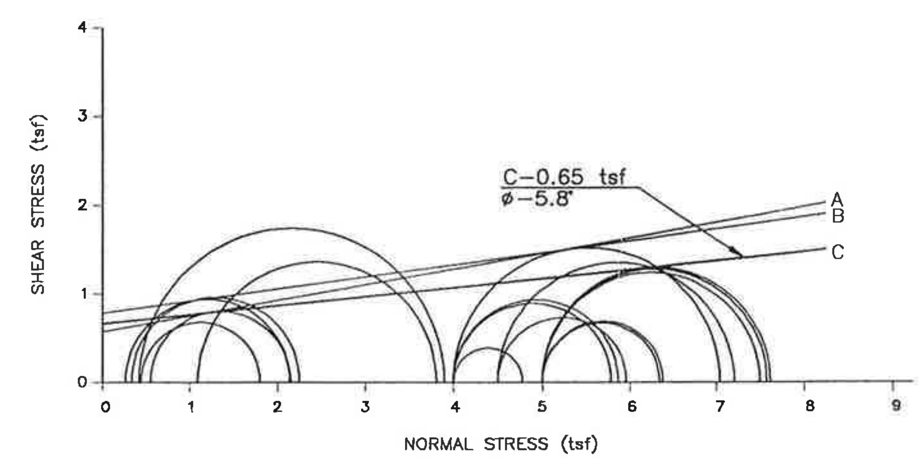
MOHR CIRCLES
EMBANKMENT FILL – EFFECTIVE STRESS PARAMETERS



MOHR CIRCLES
FOUNDATION TILL – EFFECTIVE STRESS PARAMETERS



MOHR CIRCLES
EMBANKMENT FILL – TOTAL STRESS PARAMETERS

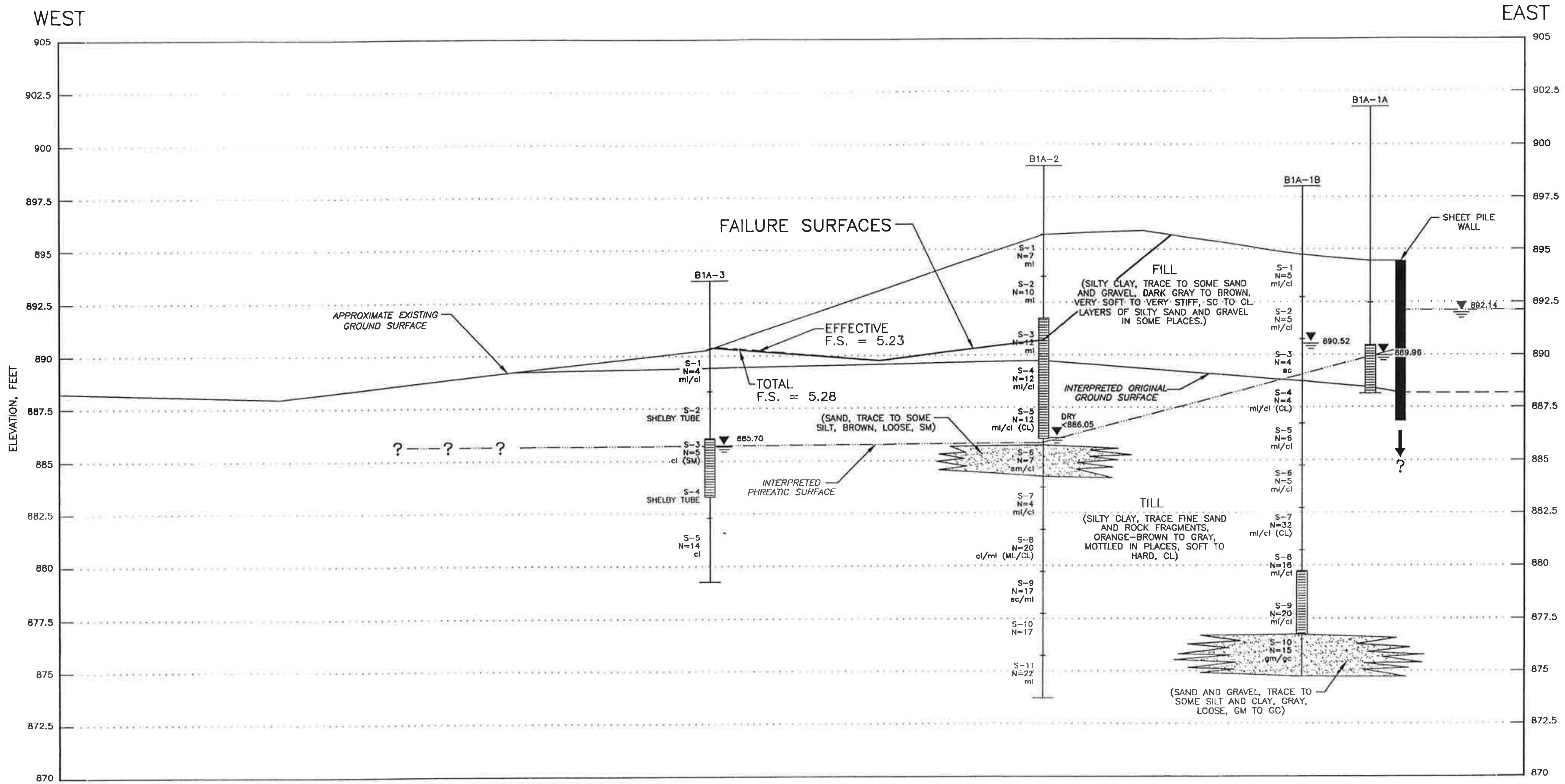


MOHR CIRCLES
FOUNDATION TILL – TOTAL STRESS PARAMETERS

FIGURE 4–1

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 10-30-96 REVISED:	MOHR CIRCLES	13/29

95-1590-E27
PLOT 1=1



SECTION 1A

STA. 50+25

SCALE 2.5 0 2.5 5 FEET

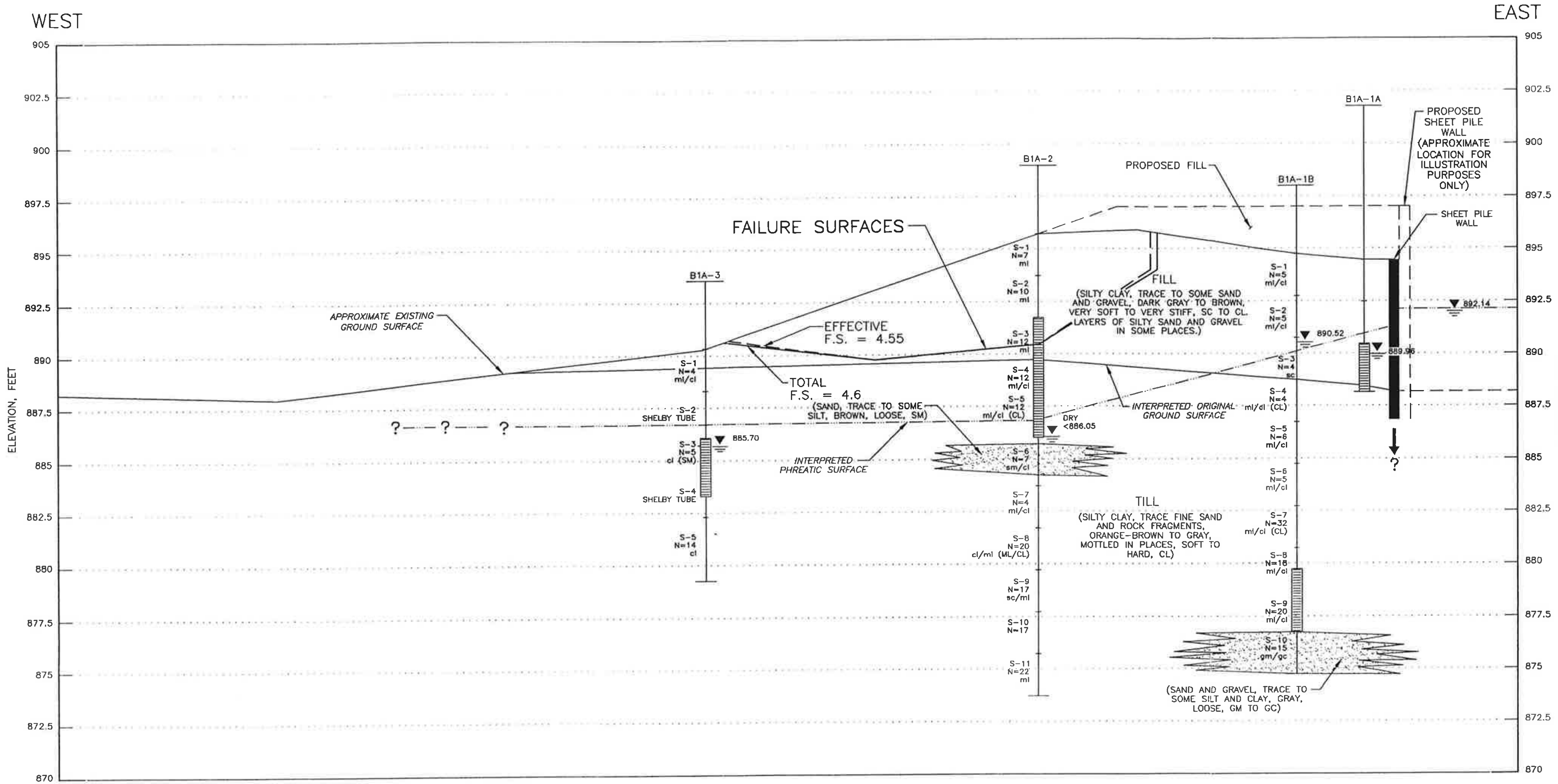
LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▤	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-2

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-26-96 REVISED:	FAILURE SURFACES - (BEFORE) NORMAL LAKE LEVEL ELEVATION 892.25 DAM CROSS SECTION 1A	14/29

95-1590-E32
PLOT 1=1



SECTION 1A
STA. 50+25

SCALE
2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▤	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-3

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

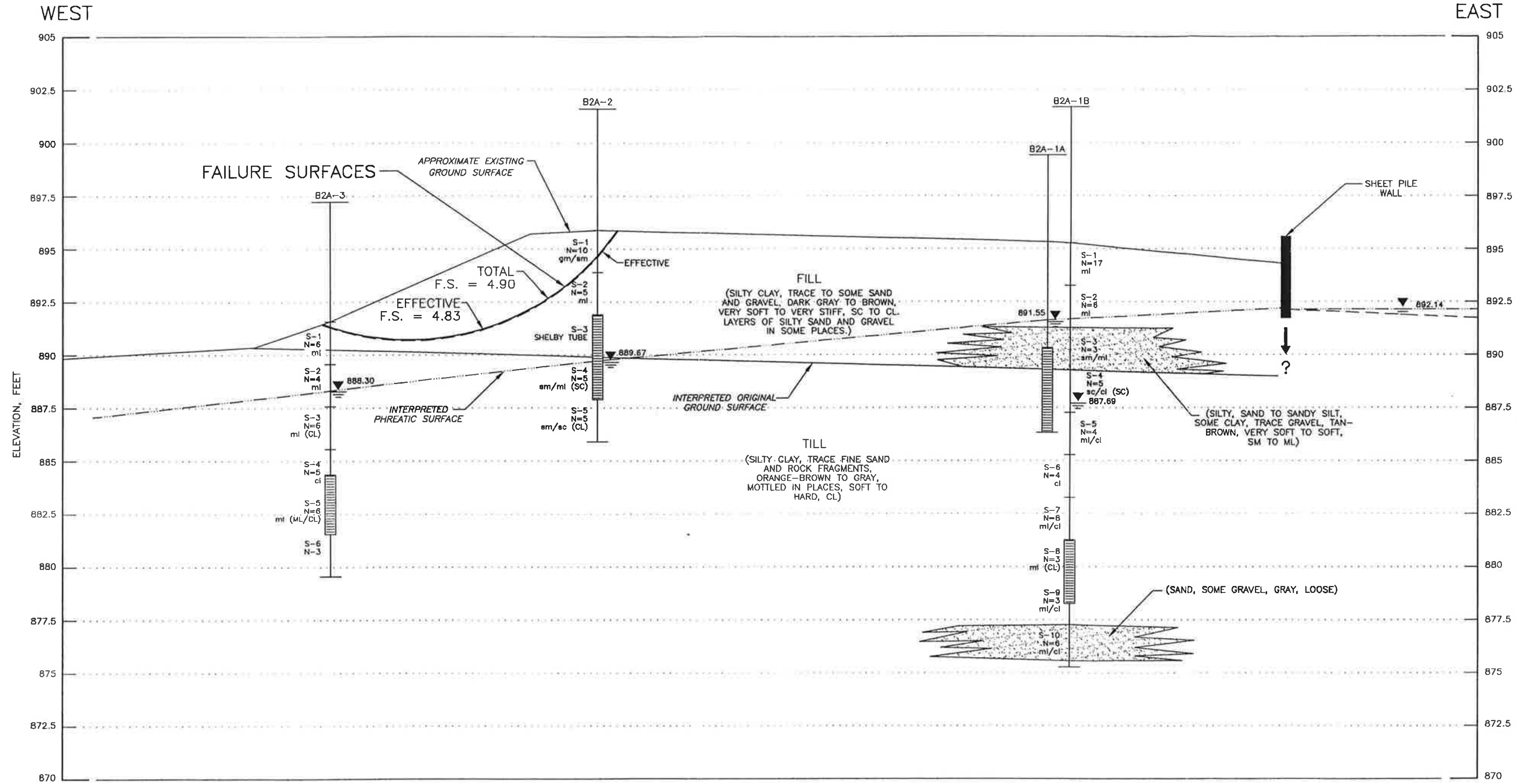
BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

DESIGNED BY:
DRAWN BY: D. J. DOBIES
CHECKED BY:
APPROVED BY:

JOB NUMBER: DNR 736 730-96-034
SCALE: AS SHOWN
DATE: 6-26-96
REVISED

FAILURE SURFACES - (AFTER)
PMF ELEVATION 897.0
DAM CROSS SECTION 1A

95-1950-E28
PLOT 1=1



SECTION 2A

STA. 64+25

SCALE

2.5 0 2.5 5 FEET

LEGEND:

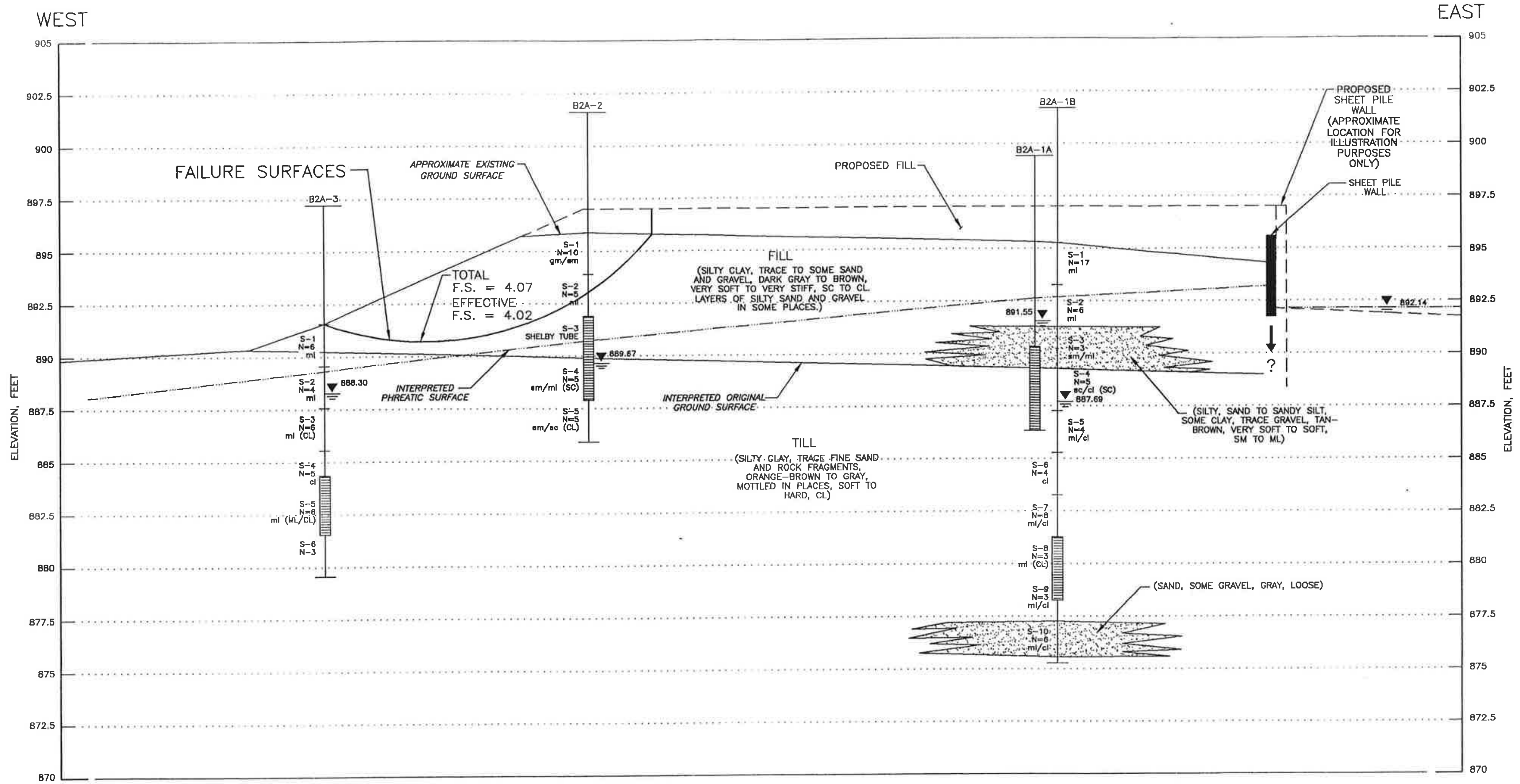
S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-4

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-26-96 REVISED	FAILURE SURFACES - (BEFORE) NORMAL LAKE LEVEL ELEVATION 892.25 DAM CROSS SECTION 2A

16/29

95-1590-E33
PLOT 1=1



SECTION 2A

STA. 64+25

SCALE

2.5 0 2.5 5 FEET

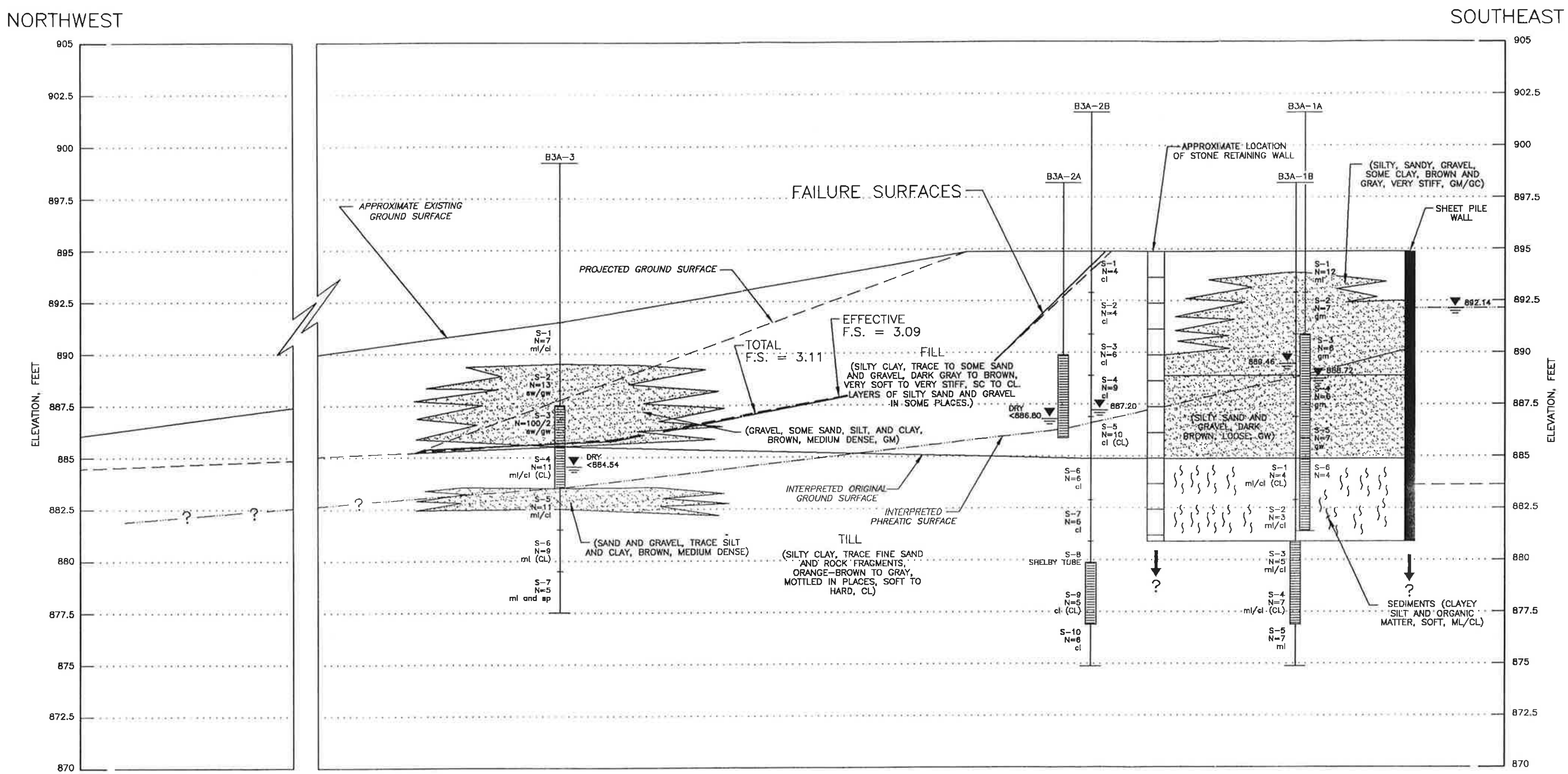
LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▽	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-5

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 8-28-96 REVISED:	FAILURE SURFACES - (AFTER) PMF ELEVATION 897.0 DAM CROSS SECTION 2A
					17/29

95-1590-E29
PLOT 1=1



SECTION 3A

STA. 140+62

SCALE
2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-6

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

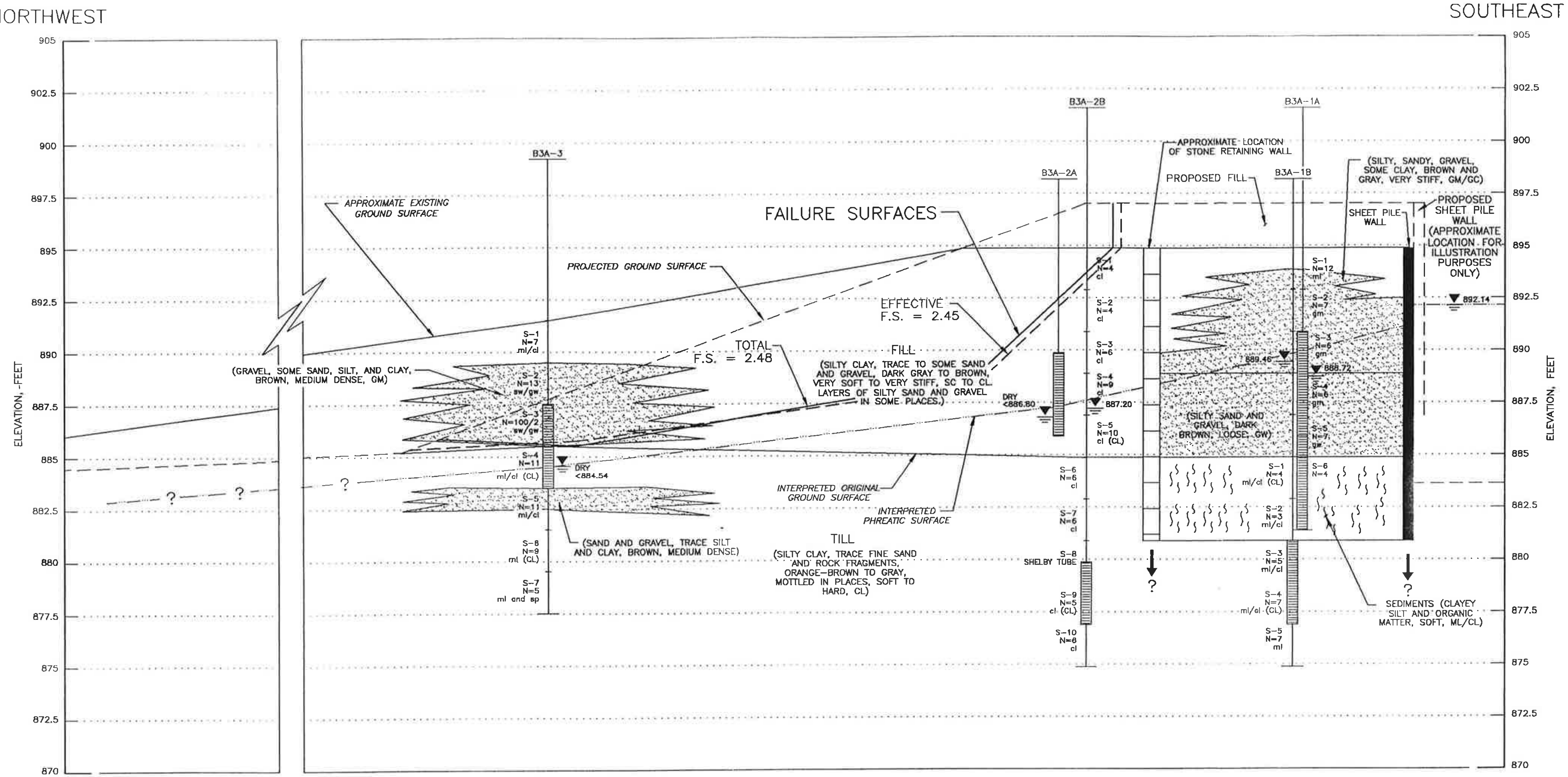
DESIGNED BY:
DRAWN BY: D. J. DOBIES
CHECKED BY:
APPROVED BY:

JOB NUMBER: DNR 736 730-96-034
SCALE: AS SHOWN
DATE: 6-26-96
REVISED:

FAILURE SURFACES - (BEFORE)
NORMAL LAKE LEVEL ELEVATION 892.25
DAM CROSS SECTION 3A

18/29

95-1590-E34
PLOT 1=1



SECTION 3A

STA. 140+62

SCALE
2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▽	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-7

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

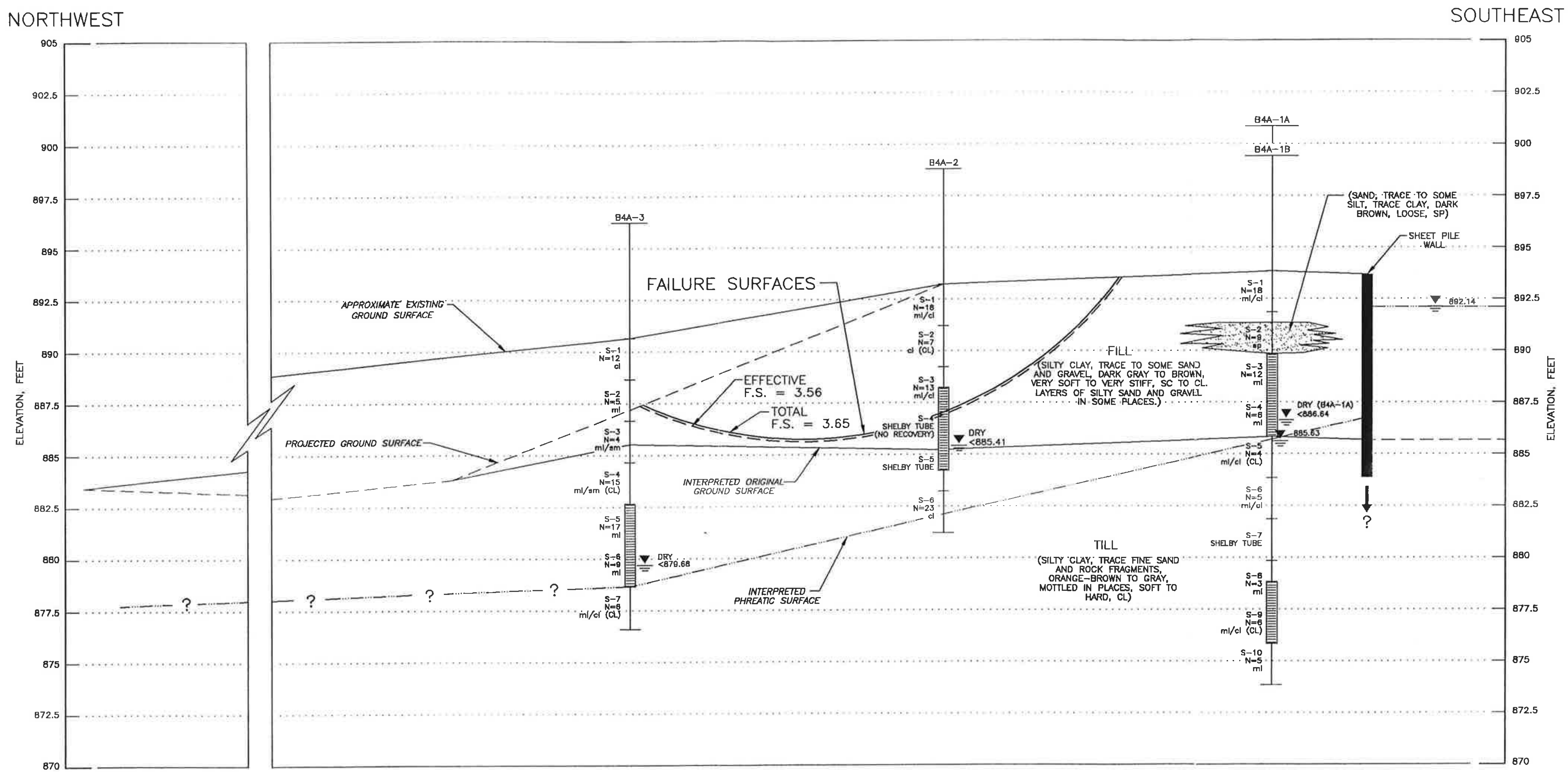
DESIGNED BY:
DRAWN BY: D. J. DOBIES
CHECKED BY:
APPROVED BY:

JOB NUMBER: DNR 730 730-96-034
SCALE: AS SHOWN
DATE: 8-26-96
REVISED:

FAILURE SURFACES - (AFTER)
PMF ELEVATION 897.0
DAM CROSS SECTION 3A

19/29

95-1590-E30
PLOT 1=1



SECTION 4A

STA. 153+30

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▥	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

SCALE
2.5 0 2.5 5 FEET

FIGURE 4-8

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

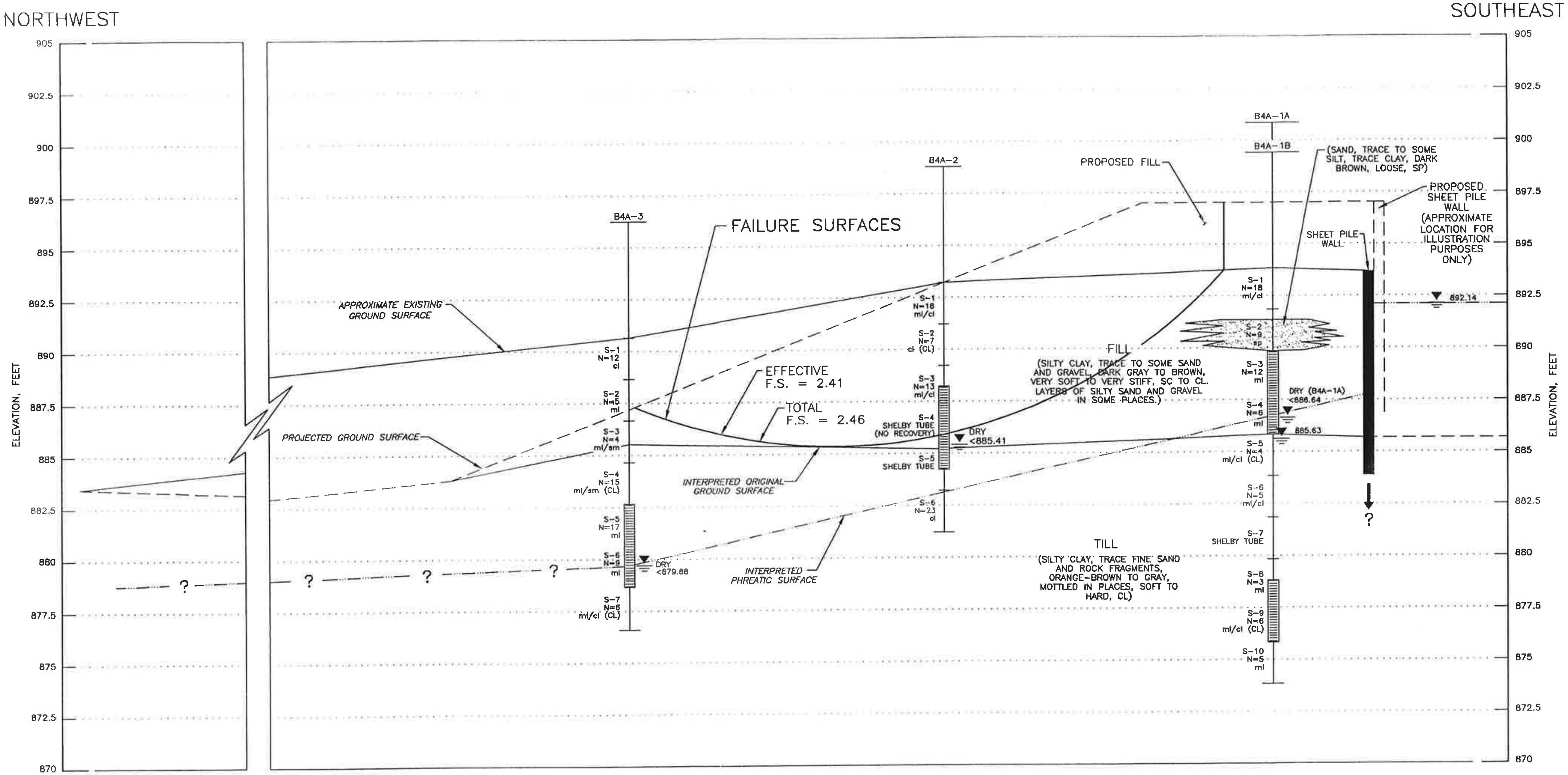
BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

DESIGNED BY:	JOB NUMBER: DNR 738 730-96-034
DRAWN BY: D. J. DOBIES	SCALE: AS SHOWN
CHECKED BY:	DATE: 6-28-98
APPROVED BY:	REVISED:

FAILURE SURFACES - (BEFORE)
NORMAL LAKE LEVEL ELEVATION 892.25
DAM CROSS SECTION 4A

20
29

95-1590-E35
PLOT 1=1



SECTION 4A

STA. 153+30

SCALE 2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-9

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

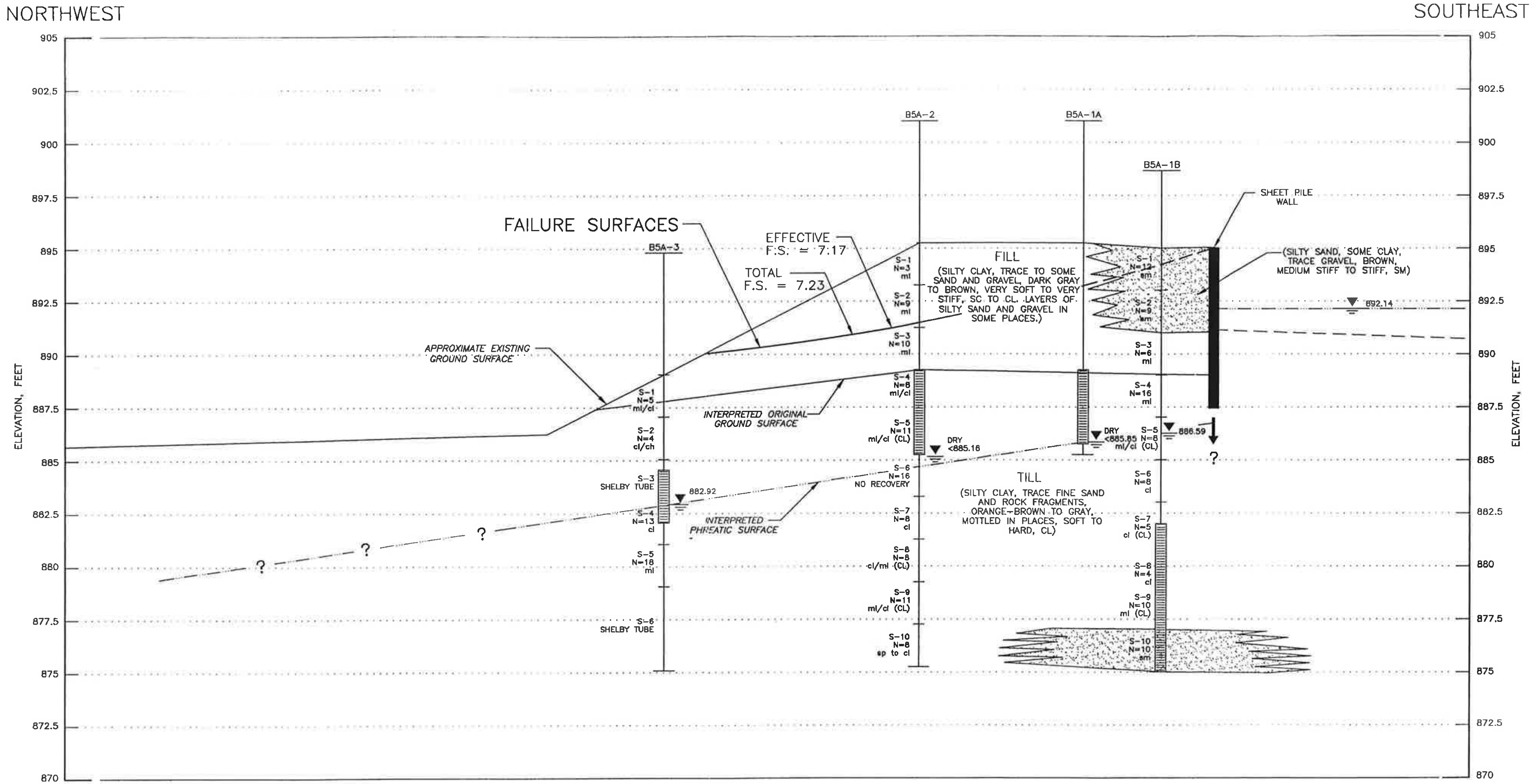
DESIGNED BY:
DRAWN BY: D. J. DOBIES
CHECKED BY:
APPROVED BY:

JOB NUMBER: DNR 738 730-96-034
SCALE: AS SHOWN
DATE: 6-26-98
REVISED:

FAILURE SURFACES - (AFTER)
PMF ELEVATION 897.0
DAM CROSS SECTION 4A

21/29

95-1950-E31
PLOT 1=1



SECTION 5A

STA. 199+80

SCALE
2.5 0 2.5 5 FEET

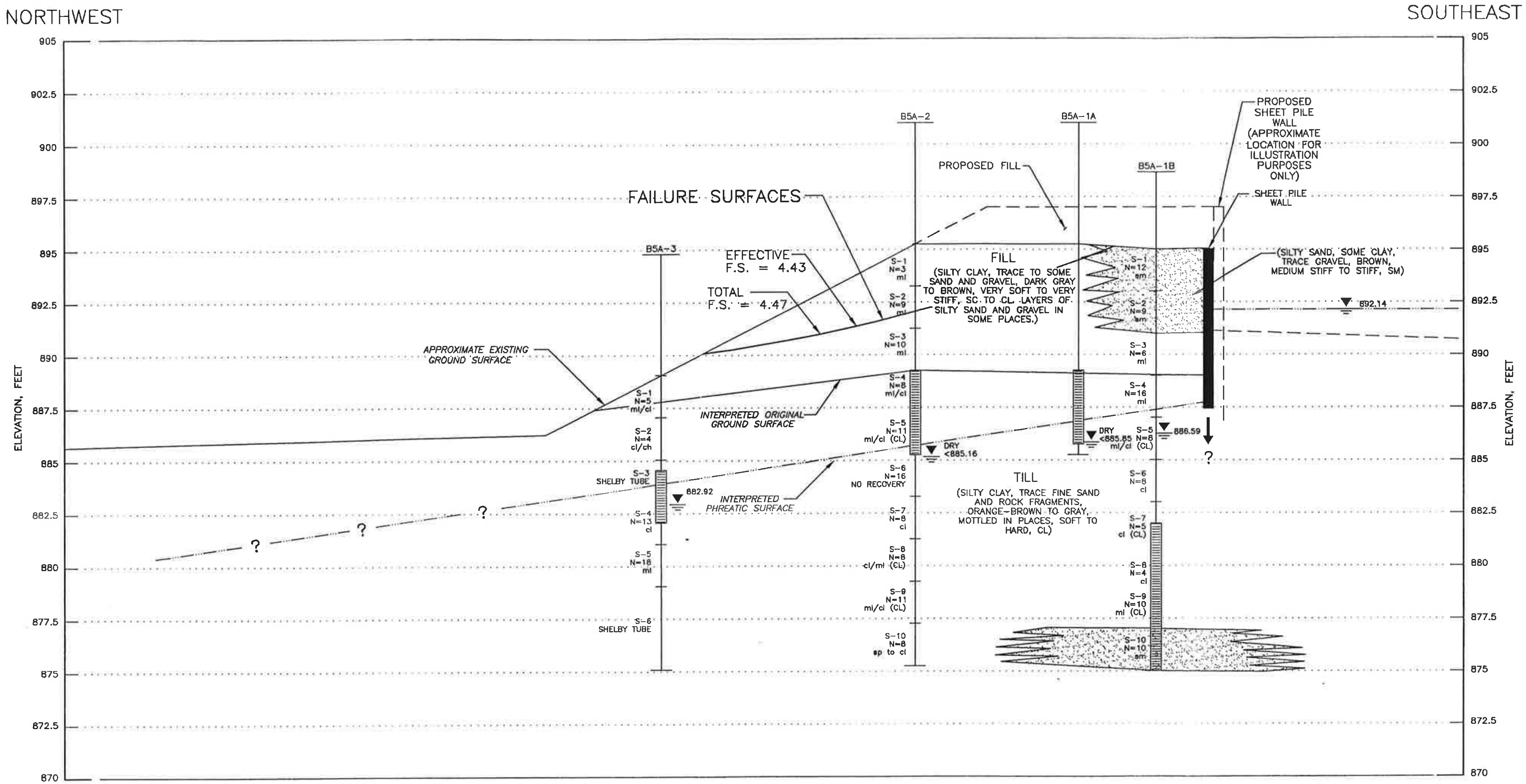
LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-10

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-26-96 REVISED:	FAILURE SURFACES - (BEFORE) NORMAL LAKE LEVEL ELEVATION 892.25 DAM CROSS SECTION 5A	22/29

95-1590-E36
PLOT 1=1



SECTION 5A
STA. 199+80

SCALE
2.5 0 2.5 5 FEET

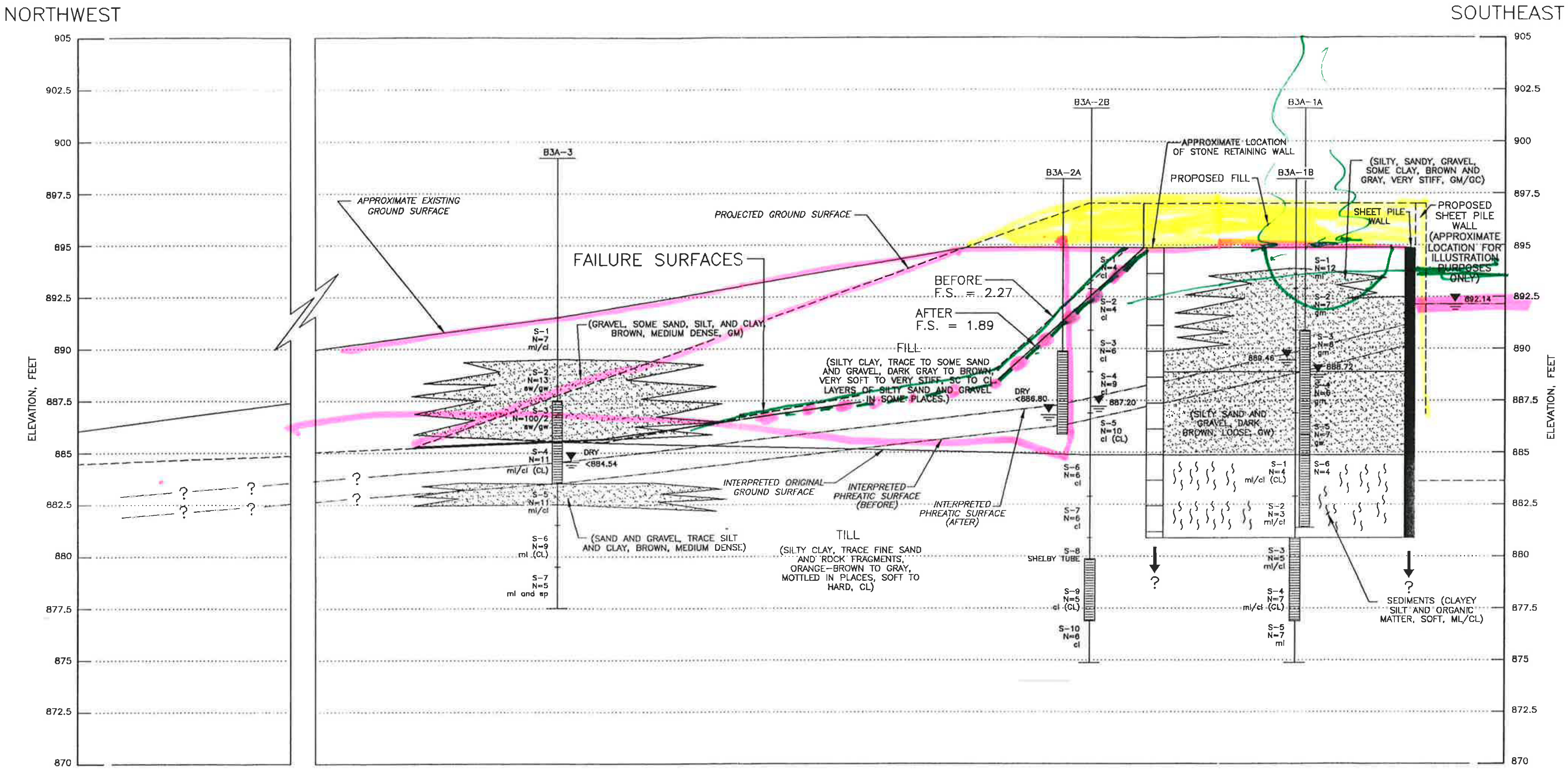
LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-11

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 8-28-96 REVISED:	FAILURE SURFACES - (AFTER) PMF ELEVATION 897.0 DAM CROSS SECTION 5A	23/29

95-1590-E37
PLOT 1=1



SECTION 3A

STA. 140+62

SCALE
2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▥	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-12

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

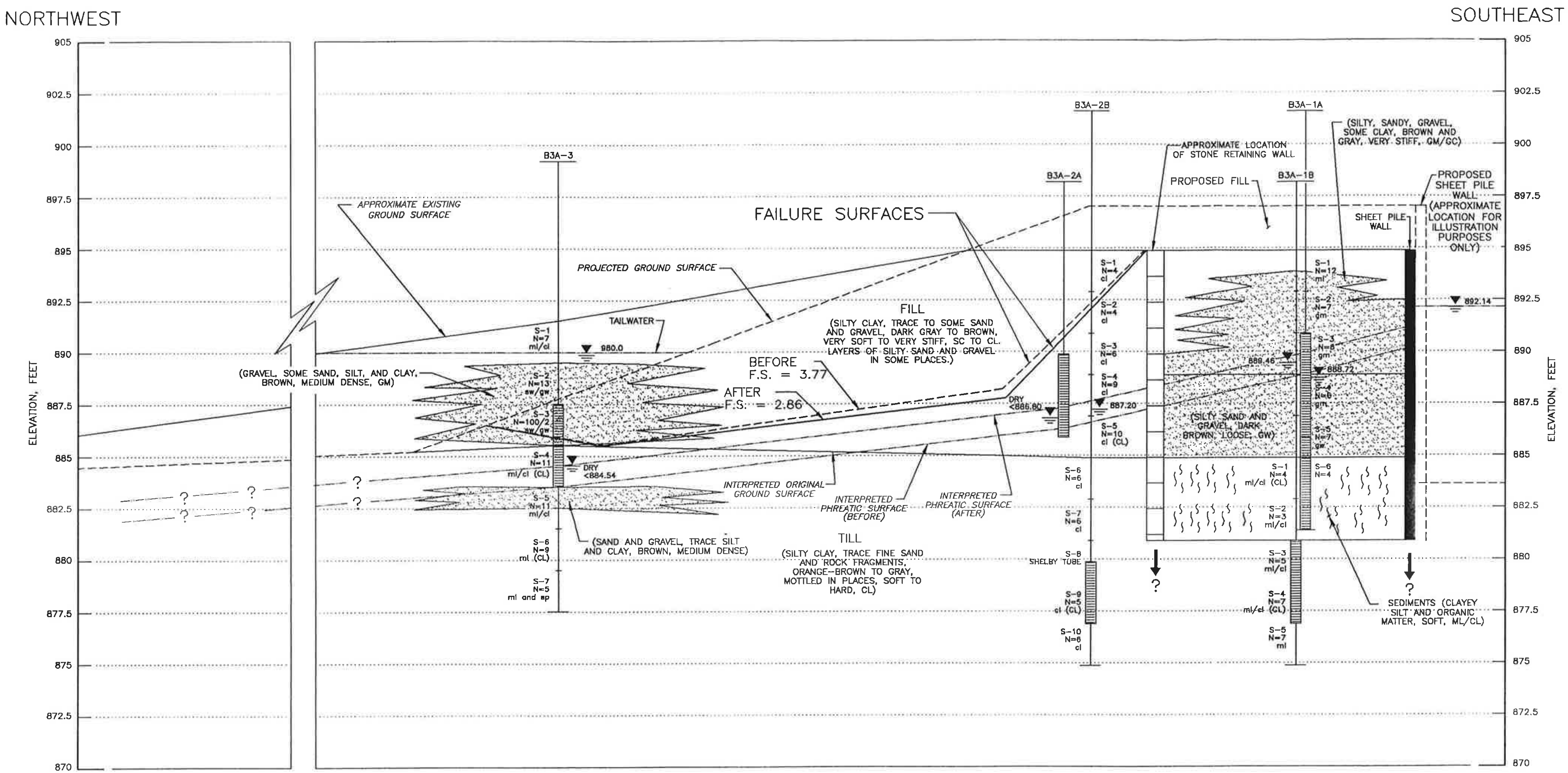
DESIGNED BY:
DRAWN BY: D. J. DOBIES
CHECKED BY:
APPROVED BY:

JOB NUMBER: DNR 736 730-96-034
SCALE: AS SHOWN
DATE: 6-28-96
REVISED:

FAILURE SURFACES (BEFORE AND AFTER)
EARTHQUAKE HORIZONTAL ACCELERATION-0.10g
DAM CROSS SECTION 3A

24/29

95-1590-E38
PLOT 1=1



SECTION 3A

STA. 140+62

SCALE
2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▥	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-13

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

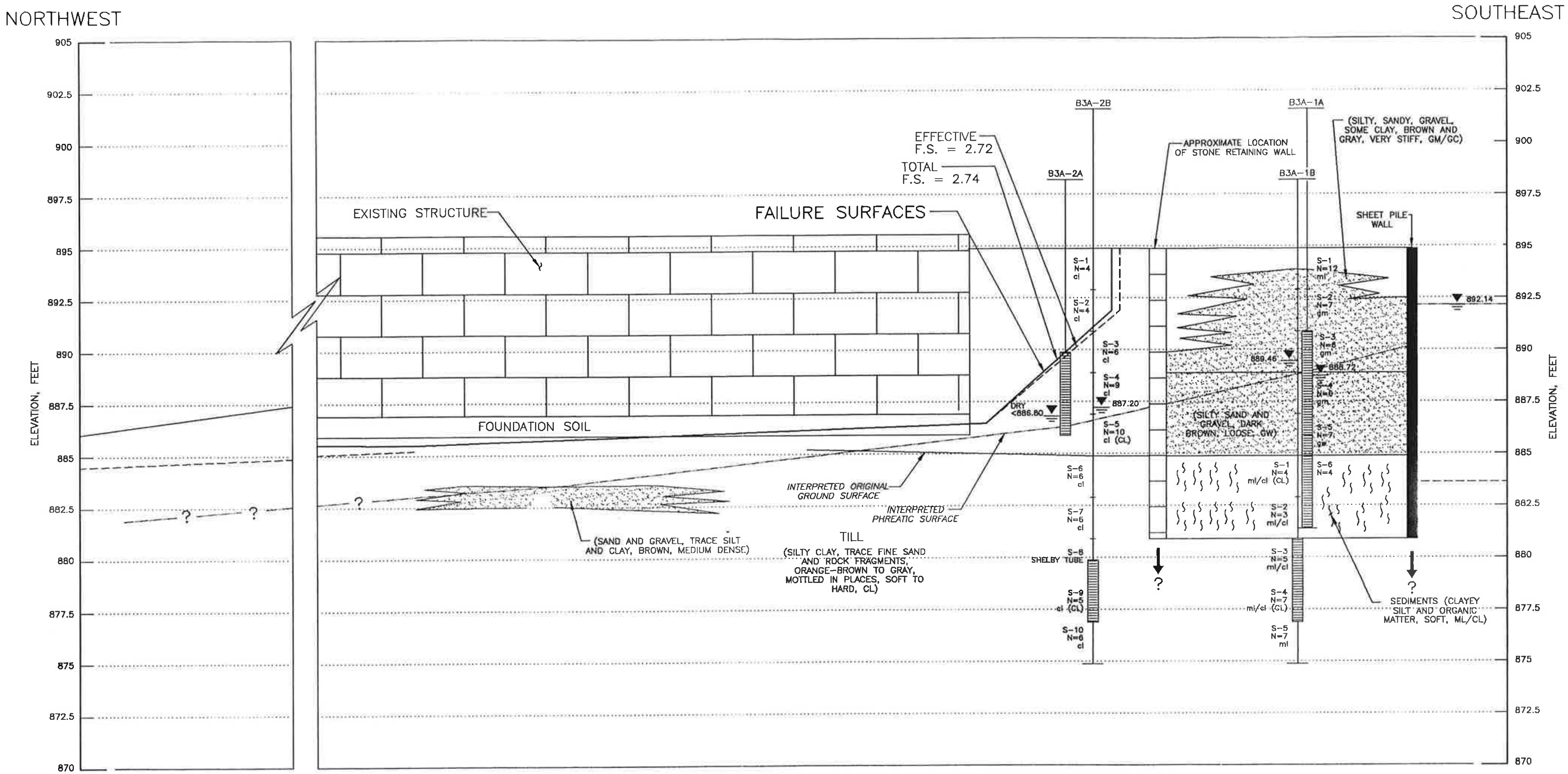
DESIGNED BY:
DRAWN BY: D. J. DOBIES
CHECKED BY:
APPROVED BY:

JOB NUMBER: DNR 736 730-96-034
SCALE: AS SHOWN
DATE: 6-26-96
REVISED:

FAILURE SURFACES – (BEFORE AND AFTER)
TAILWATER ELEVATION 890.0
DAM CROSS SECTION 3A

25/29

95-1590-E39
PLOT 1=1



SECTION 3A

STA. 140+62

SCALE
2.5 0 2.5 5 FEET

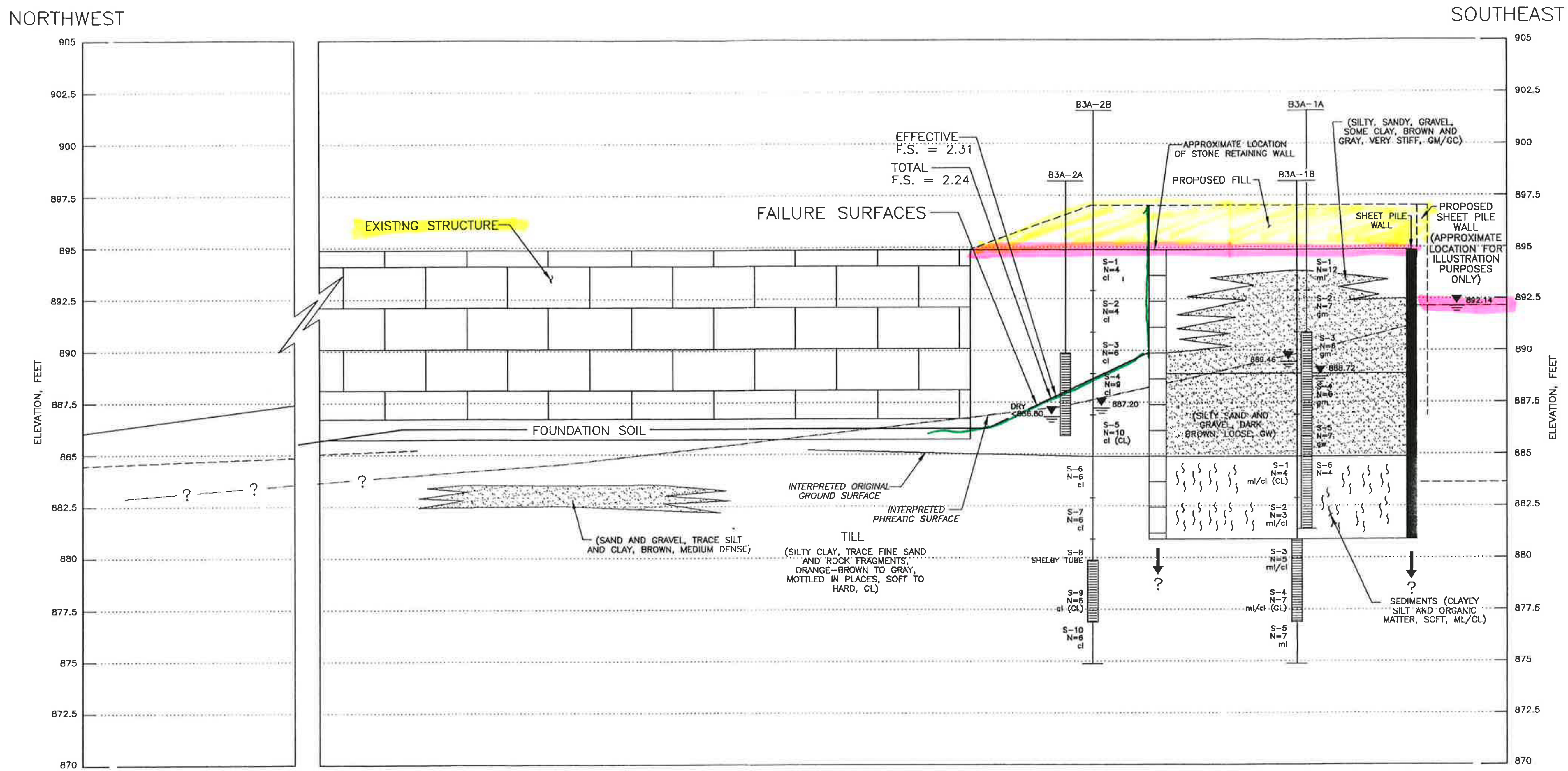
LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▽	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-14

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-28-96 REVISED:	FAILURE SURFACES – (BEFORE) NORMAL LAKE LEVEL ELEVATION 892.25 DAM CROSS SECTION 3A WITH STRUCTURE	26/29

95-1590-E40
PLOT 1=1



SECTION 3A

STA. 140+62

SCALE 2.5 0 2.5 5 FEET

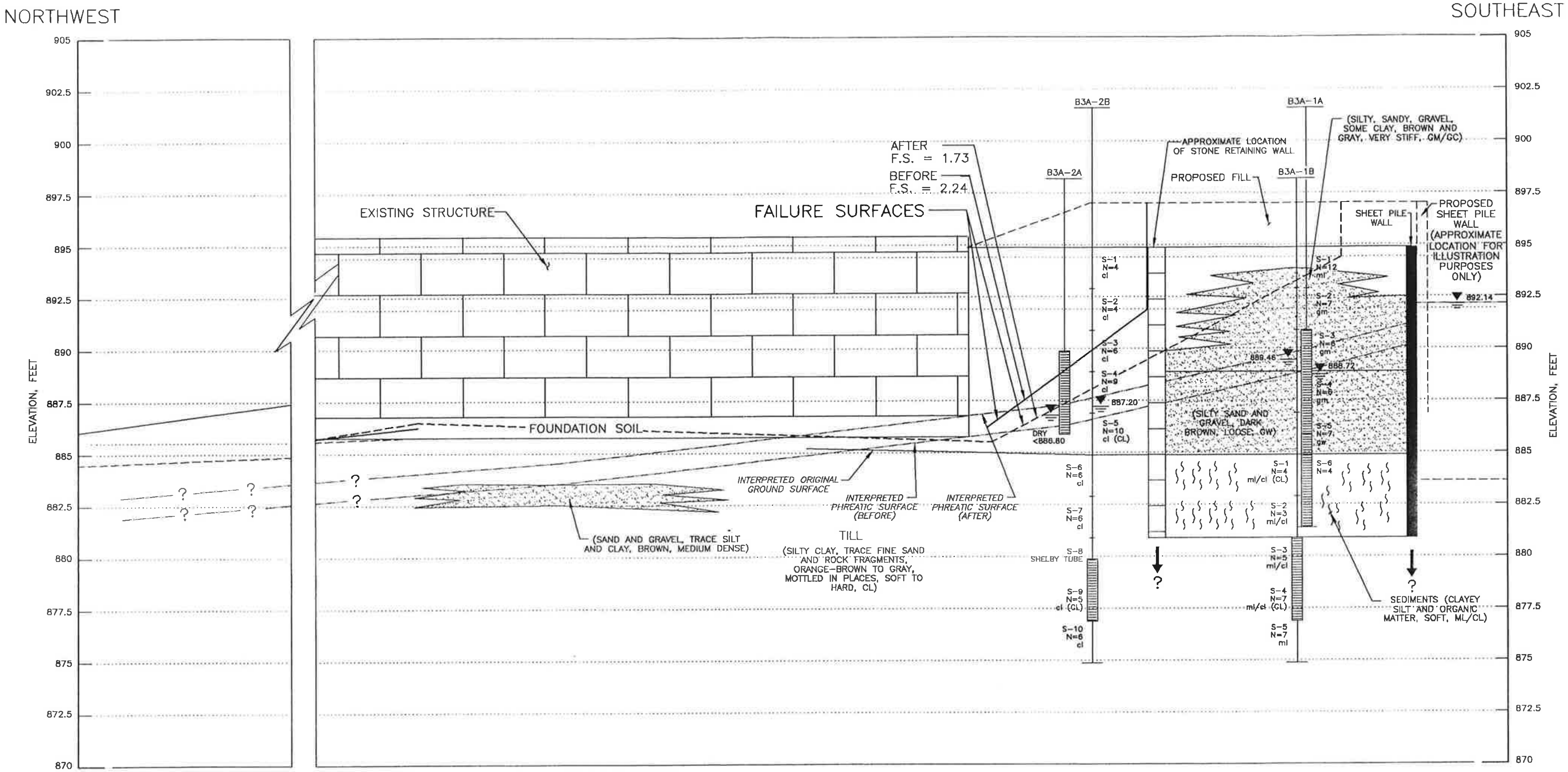
LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▯	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-15

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-26-96 REVISED:	FAILURE SURFACES – (AFTER) PMF ELEVATION 897.0 DAM CROSS SECTION 3A WITH STRUCTURE	27/29

95-1590-E41
PLOT 1=1



SECTION 3A

STA. 140+62

SCALE
2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-16

Paul C. Rizzo Associates, Inc.
4605 HILTON CORPORATE DRIVE
COLUMBUS, OHIO

STATE of OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENGINEERING

BUCKEYE LAKE STATE PARK
DAM STABILITY STUDY
FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO

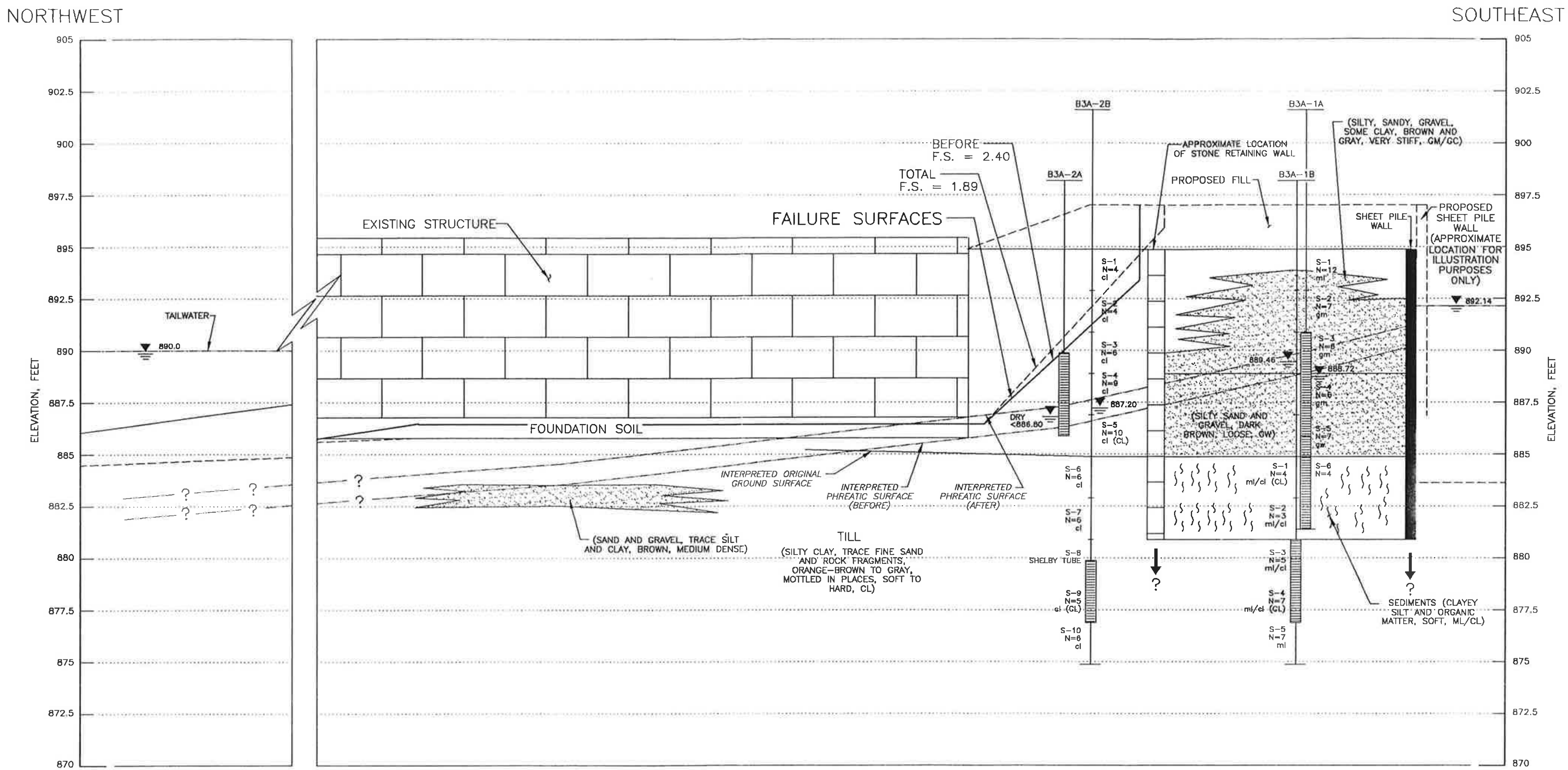
DESIGNED BY:
DRAWN BY: D. J. DOBIES
CHECKED BY:
APPROVED BY:

JOB NUMBER: DNR 738 730-96-034
SCALE: AS SHOWN
DATE: 6-26-96
REVISED:

FAILURE SURFACES – (BEFORE AND AFTER) EARTHQUAKE HORIZONTAL ACCELERATION–0.10g DAM CROSS SECTION 3A WITH STRUCTURE

28
29

95-1590-E42
PLOT 1=1



SECTION 3A

STA. 140+62

SCALE
2.5 0 2.5 5 FEET

LEGEND:

S-1	SAMPLE NO.
N=5	STANDARD PENETRATION TEST "N"
ml/cl	FIELD DETERMINED U.S.C.S. CLASSIFICATION
(CL)	LABORATORY DETERMINED U.S.C.S. CLASSIFICATION
▼	STATIC WATER LEVEL (OCTOBER 10, 1996) LESS THAN SYMBOL (<) AND ELEVATION INDICATE POROUS STONE BOTTOM ELEVATION
▥	PIEZOMETER MONITORED INTERVAL (INCLUDES SAND PACK LENGTH ABOVE AND BELOW POROUS STONE)

FIGURE 4-17

Paul C. Rizzo Associates, Inc. 4605 HILTON CORPORATE DRIVE COLUMBUS, OHIO	STATE of OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF ENGINEERING	BUCKEYE LAKE STATE PARK DAM STABILITY STUDY FAIRFIELD, LICKING AND PERRY COUNTIES, OHIO	DESIGNED BY: DRAWN BY: D. J. DOBIES CHECKED BY: APPROVED BY:	JOB NUMBER: DNR 736 730-96-034 SCALE: AS SHOWN DATE: 6-26-96 REVISED:	FAILURE SURFACES – (BEFORE AND AFTER) TAILWATER ELEVATION 890.0 DAM CROSS SECTION 3A WITH STRUCTURE	29/29

APPENDIX A

BORING LOGS AND PIEZOMETER CONSTRUCTION DIAGRAMS

Boring Logs

CAD FILE NUMBER 93-1351-B4

DRAWN BY | K.L.M. 2-24-94 | CHECKED BY BFV 4/6/94 | APPROVED BY [signature] 7/1/?? | PLOT 1=1

GUIDE FOR SOIL DESCRIPTIONS

1. SECONDARY SOIL TYPE (SILTY, ETC.) (30–40% BY WEIGHT)
2. PRIMARY SOIL TYPE (CLAY, ETC.)
3. DESCRIPTIVE TERMS, SUCH AS:
   - SOME (12–30% BY WEIGHT)
   - TRACE (5–12% BY WEIGHT)
   - LENS (≤ 1" THICKNESS)
   - LAYER (> 1" THICKNESS)
   - INTERBEDDED
   - SLICKENSIDED
   - POCKETS, ETC.
4. COLOR (INCL. DARK, LIGHT, MED.)
5. SOIL DENSITY/CONSISTENCY
6. MOISTURE (DRY, MOIST, OR WET)

CONSISTE

CONSISTENCY	UNCONFINED COMPRESSIVE STRENGTH (TONS PER SQUARE FOOT)
VERY SOFT	LESS THAN 0.25
SOFT	0.25 TO 0.50
MEDIUM STIFF	0.50 TO 1.0
STIFF	1.0 TO 2.0
VERY STIFF	2.0 TO 4.0
HARD	MORE THAN 4.0

MEASURED CONSISTENCY: UNCONFINED COMP
RESULTS OF TORVANE TESTS ARE IDENTIFIED

COMPARISON

CLEAR SIEVE OPENINGS: 3" 1-1/2" 3/4" 3/8" #4 #10

U.S. S SIEVE

1000. 100. 10. 1.

COBBLES	GRAVEL COARSE	GRAVEL FINE	COARSE	ME

USCS C

COARSE-GRAINED SOILS

CLEAN GRAVELS (LITTLE OR NO FINES)	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURE
	GC	CLAYEY GRAVELS
CLEAN SANDS (LITTLE OR NO FINES)	SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)	SM	SILTY SANDS, SAND-CLAY MIXTURES
	SC	CLAYEY SANDS, SAND-CLAY MIXTURES

ERIAL SYMBOLS

STONE

TONE

DSTONE

SIVE MUDSTONE
LAYSTONE

E

MITE

LOMERATE

OUS ROCK

MORPHIC ROCK

MISCELLANEOUS

- SLAG
- FILL OR MINE SPOIL
- REFUSE
- CONCRETE
- VOID (INDICATE SIZE OF VOID)
- WATER
- APPROXIMATE EXISTING GROUND SURFACE
- APPROXIMATE TOP OF ROCK

MB
TH CRUMBLY EDGES
BUT WITH RESISTANT
T WITH VERY RESISTANT

ROCK DISCONTINUITIES/ FRACTURE SPACING

DESCRIPTIVE TERMS	SPACING
VERY BROKEN	LESS THAN 1 IN.
BROKEN	1 IN. TO 3 IN.
SLIGHTLY BROKEN	3 IN. TO 6 IN.
UNBROKEN	6 IN. AND GREATER

NOTES

1. THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL AND ROCK CONDITIONS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS.
2. THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

GENERAL NOTES AND LEGEND– BORINGS IN SOIL AND ROCK

PREPARED FOR

PIKE SANITATION, INC.
WAVERLY, OHIO

Paul C. Rizzo Associates, Inc.
CONSULTANTS

APR 94

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B1A-1A

COORDINATES
N 697113.76 E 1992975.29

SURFACE EL: 894.73

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
890.00				Boring drilled to 8.5' below ground surface without sampling. Refer to B1A-1B boring log for subsurface details.		
	5					
886.23				BOTTOM OF BORING AT 8.5'		
	10					
	15					
	20					
	25					
	30					
	35					

DATE STARTED: 7-23-96
DATE COMPLETED: 7-23-96
FIELD GEOLOGIST: JZD
CHECKED BY: JZD/RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: – DATE/TIME: –
GWL: DEPTH: – DATE/TIME: –
DRILLING METHOD: 3-7/8" water rotary, no sampling (0.0' to 8.5')

NOTES:
DRILL RIG: Track mounted SIMCO
DRILLER: Todd England
* penetrometer (tons per square foot))

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B1A-1B

COORDINATES N 697115.57 E 1992971.97

SURFACE EL: 894.45

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 7 5		Clayey silt, some sand, brown to black, medium stiff to stiff, dry (Fill)	ml/cl	*0.5 top, 1.0 bottom *0.75
		S-2 2 5		Same as above, moist to wet	ml/cl	JZD instructs drill to remove basket from spoon to improve sample recovery
890.00	5	S-3 8 4		Clayey sand/sandy clay, some silt and rock fragments, gray brown, very soft, wet (Fill) 6.0'	sc/cl	*0.25 throughout sample
		S-4 20 4		Silty clay, trace sand, dark gray to dark brown, trace organic matter, very soft, wet 8.0'	ml/cl	*0.25 top, 0.0 bottom
	10	S-5 14 6		Silty clay, gray and brown mottled, soft to stiff, moist (Till)	ml/cl	*1.25 top, 0.5 bottom
		S-6 14 5		Same as above, trace to some gravel, moist to wet 12.0'	ml/cl	*0.75 top, 0.5 bottom
		S-7 15 32		Same as above, very hard, moist, increase in gravel content	ml/cl	*4.5 and throughout sample
880.00	15	S-8 0 18		No recovery		JZD instructs driller to place basket in spoon
		S-9 6 20		Clayey silt, some gravel, gray, very stiff to hard, moist	ml/cl	*4.5 + top, 2.5 bottom
874.45	20	S-10 7 15		Sand and gravel, trace to some silt and clay, gray, loose, wet 20.0'	gm/gc	poor recovery
				BOTTOM OF BORING AT 20.0'		
	25					
	30					
	35					

DATE STARTED: 7-23-96
DATE COMPLETED: 7-23-96
FIELD GEOLOGIST: JZD
CHECKED BY: JZD/RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: – DATE/TIME: –
GWL: DEPTH: – DATE/TIME: –
DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' to 20.0')

NOTES:
DRILL RIG: Track mounted SIMCO
DRILLER: Todd England
* penetrometer (tons per square foot))

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B1A-2

COORDINATES
N 697122.47 E 1992961.92

SURFACE EL: 895.72

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 9 7		Clayey silt, trace to some sand and rock fragments, tan and dark brown, stiff, dry (Fill)	ml	*1.25
		S-2 10 10		Clayey silt, some gravel, trace to some sand, orange brown to brown, stiff to very stiff, moist (Fill)	ml	*2.25 top, 1.75 bottom
890.00	5	S-3 9 12		Sandy silt, trace clay, dark brown to black, tan near bottom, stiff to very stiff, moist (Fill) 6.0'	ml	*1.25 top, 2.25 bottom
		S-4 8 12		Clayey silt, black to yellow-brown, organic in upper portion, stiff to very stiff, moist	ml/ cl	*1.5 top, 3.0 bottom
	10	S-5 11 12		Clayey silt, trace to some sand, trace gravel, dark brown at top, orange brown at bottom, very stiff, moist (Till)	ml/ cl	*2.0 top, 2.75 bottom
		S-6 14 7		Sand, trace to some silt and clay, brown, loose, wet Clay, trace silt, orange-brown to gray mottled, very stiff, dry at 11.5'	sm cl	*0.5 top, 3.0 bottom
		S-7 17.5 4		Silty clay to clay, trace to some sand, gray and brown, weakly laminated, stiff, clay content increases toward	ml/ cl	*1.0 throughout sample
880.00	15	S-8 14 20		Silty clay, trace fine sand laminae, gray, stiff to very stiff, moist, sand wet	cl ml sc	*1.5 top, 3.25 bottom
		S-9 6 17		Same as above	ml	*1.5 poor return sample
		S-10 0 17		No recovery		no recovery, JZD instructs driller to take 1 more sample from 20.0' to 22.0'
873.72	20	S-11 8 22		Clayey silt, trace to some sand and gravel, gray, very stiff, moist 22.0'	ml	*2.75 top, 2.0 bottom
	25			BOTTOM OF BORING AT 22.0'		
	30					
	35					

DATE STARTED: 7-23-96
DATE COMPLETED: 7-23-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: – DATE/TIME: –
GWL: DEPTH: – DATE/TIME: –
DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' to 22.0')

NOTES:
DRILL RIG: Track mounted SIMCO
DRILLER: Todd England
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B1A-3

COORDINATES
N 697131.15 E 1992949.02

SURFACE EL: 890.31

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
890.00		S-1 / 9 / 4		Silt, some clay, trace sand, organic material (topsoil) 0.9'	ml	
		S-2 / 28 / N/A		Silty clay, trace sand, mottled orange brown and gray, soft, moist (Till)	cl	*0.5
				Shelby Tube from 2.0' to 4.5'		
	5	S-3 / 15 / 5		Silty clay, trace sand, mottled orange brown, and gray, fine sandy silt seams @ 6.0' to 6.1' and 6.4' to 6.5', soft, moist to wet	cl	*0.5
		ST-4 / 28 / N/A		Shelby Tube from 6.5' to 9.0'		
880.00	10	S-5 / 12 / 14		Silty clay, laminated red-brown to gray, stiff, moist to wet 11.0'		Upper 0.3' is red brown, rest is gray, weaker lamination in red brown material.
879.31						
	15			BOTTOM OF BORING AT 11.0'		
	20					
	25					
	30					
	35					

DATE STARTED: 7-25-96	GWL: DEPTH: – DATE/TIME: –	NOTES:
DATE COMPLETED: 7-25-96	GWL: DEPTH: – DATE/TIME: –	DRILL RIG: Track mounted SIMCO
FIELD GEOLOGIST: RAS	DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' - 11.0')	DRILLER: Todd England
CHECKED BY: JZD/RAS		* hand penetrometer (tons per square foot)
DRILLING CO.: CTL Drilling		

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B2A-1A

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	COORDINATES N 698313.45 E 1993706.34 SURFACE EL: 895.40 DESCRIPTION	USCS SYMBOL	REMARKS
				Boring drilled to 9.0' below ground surface without sampling. Refer to B2A-1B boring log for subsurface details.		
890.00	5					
886.40				BOTTOM OF BORING AT 9.0'		
	10					
	15					
	20					
	25					
	30					
	35					

DATE STARTED: 7-22-96	GWL: DEPTH: -- DATE/TIME: --	NOTES:
DATE COMPLETED: 7-22-96	GWL: DEPTH: -- DATE/TIME: --	DRILL RIG: Track mounted SIMCO
FIELD GEOLOGIST: JZD	DRILLING METHOD: 4-1/4" I.D. Hollow Stem Augers,	DRILLER: Todd England
CHECKED BY: RAS	no sampling (0.0' - 9.0')	* penetrometer (tons per square foot)
DRILLING CO.: CTL Drilling		

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 | SITE: Buckeye Lake

LOG OF BORING NO. B2A-1B

COORDINATES
N 698308.66 E 1993704.14

SURFACE EL: 895.34

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 16 17		Sandy silt, some clay and rock fragments, brown, stiff to very stiff, dry (Fill)	ml	*1.5 top, 3.75 bottom
		S-2 15 6		Clayey silt, trace to some rock fragments and sand, tan to brown, very stiff, dry 4.0'	ml	*3.75 top, 3.25 bottom
890.00	5	S-3 15 3		Silty sand/sandy silt, some clay, trace gravel, tan brown, very soft to soft (Fill) 6.0'	sm/ ml	*0.0 top, 0.5 bottom wet
		S-4 14 5		Sandy clay, some silt, trace rock fragments, mottled gray and brown, soft to medium stiff, wet (Till)	sc/ cl	*1.0 top, 0.5 bottom
		S-5 15 4		Same as above, mottled tan and brown, wet	ml/ cl	*1.0 throughout sample
	10	S-6 14 4		Clay, trace to some silt, mottled gray and tan, medium stiff to stiff, moist	cl	*0.75 top, 1.0 bottom
		S-7 9 8		Same as above, trace to some silt, laminated, moist 13.0'	ml/ cl	*0.25 top, 0.5 bottom
				Silt, some clay, gray, very soft to soft, weakly laminated in places, wet (Till)		
880.00	15	S-8 18 3		Same as above	ml	*0.25 throughout sample
		S-9 14 3		Same as above, weakly laminated, wet 18.0'	ml/ cl	*0.0 top, 0.25 bottom
875.34	20	S-10 24 6		Sand, some gravel, gray, loose 20.0'	ml/ cl	*0.0 top, 0.25 bottom
				BOTTOM OF BORING AT 20.0'		
	25					
	30					
	35					

DATE STARTED: 7-22-96
DATE COMPLETED: 7-22-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: – DATE/TIME: –
GWL: DEPTH: – DATE/TIME: –
DRILLING METHOD: 4-1/4" I.D. Hollow Stem Augers continuous split spoon sampling (0.0' - 20.0')

NOTES:
DRILL RIG: Track mounted SIMCO
DRILLER: Todd England
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B2A-2

COORDINATES
N 698321.39 E 1993685.80

SURFACE EL: 895.97

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 16 10		Sand and gravel, some silt and clay, gray and brown, dry (Fill)	gm/ sm	*2.0, 1.75, 3.0 bottom
		S-2 9 5		Silty clay, somet sand and gravel, brown, very soft, wet (Fill)	ml	*0.0 throughout sample
890.00	5	ST-3 24		Shelby tube 6.0'		
		S-4 21 5		Sandy, clayey, silt, clay content increases with depth, orange brown, brown and gray mottled, very soft, moist to wet (Till)	sm/ ml	*0.0, 0.25, 0.5 bottom
885.97	10	S-5 18 5		Same as above, less silt and clay content, wet 10.0'	sm/ ml	*1.0, 0.5 1.5 bottom
				BOTTOM OF BORING AT 10.0'		
	15					
	20					
	25					
	30					
	35					

DATE STARTED: 8-5-96
DATE COMPLETED: 8-5-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: – DATE/TIME: –
GWL: DEPTH: – DATE/TIME: –
DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' - 10.0')

NOTES:
DRILL RIG: CME 75
DRILLER: Chris
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B2A-3

COORDINATES: N 698329.81 E 1993675.24

SURFACE EL: 891.64

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
890.00		S-1 7 6		Clay, some silt and sand, dark brown, soft to stiff, moist (Fill) 2.0'	ml	*1.5 top, 0.25 bottom
		S-2 16 4		Clay, some silt and sand, orange brown, brown and gray mottled, soft to stiff, moist (Till)	ml	*.75 top, .25 bottom
	5	S-3 18 6		Clayey silt, some sand, orange brown and gray mottled, medium stiff to stiff, moist	ml	*.75, 1.25 bottom
		S-4 17 5		Clay, trace to some silt, trace sand, brown and gray mottled, faintly laminated, medium stiff to stiff, moist	cl	*0.5 top, 1.5 bottom
		S-5 17 6		Silt, trace clay, gray, soft to medium stiff, wet	ml	*0.5 throughout sample
880.00	10	S-6 19 3		Clayey silt, gray, trace organic material, very soft to soft wet 12.0'		*0.5 top, 0.0 bottom
879.64				BOTTOM OF BORING AT 12.0'		
	15					
	20					
	25					
	30					
	35					

DATE STARTED: 7-23-96
DATE COMPLETED: 7-23-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: -- DATE/TIME: --
GWL: DEPTH: -- DATE/TIME: --
DRILLING METHOD: 3-7/8" water rotary
continuous split spoon sampling (0.0'-12.0')

NOTES:
DRILL RIG: Track mounted SIMCO
DRILLER: Todd England
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B3A-1A

COORDINATES
N 699696.65 E 1999934.46

SURFACE EL: 894.99

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 14 12		Silt, some clay, trace roots, dark brown, soft, moist (topsoil) 1.0'	ml	*0.5
		S-2 12 7		Gravelly, sandy, silt, some clay, brown and gray, very stiff, moist (Fill)		*2.5
				Same as above, more sand in places, no structure, no bedding, moist		*2.25, heterogenous mixture of silt, clay, gravel, sand
890.00	5	S-3 9 6		Same as above, moist 6.0'		*2.5
		S-4 6 6		Silty sand and gravel, trace clay, brown, loose, wet (Fill). No structure, no bedding	gw	Non cohesive, will go to sand basket in spoon
		S-5 6 7		Same as above, loose, wet	gw	Hole caving to 7.5' Bring in augers, drill augers to 10.0'. Clean out with rotary bit, open to 11.5'.
	10	S-6 3 4		Same as above, slightly more silt, very loose, wet		Take sample to 13.5', 1" Recovery all gravel/sand (fill) I believe we are in gravel backfill behind sheet piling. Will set shallow nested piezometer at this location.
881.49				13.5'		
				BOTTOM OF BORING AT 13.5'		
	15					
	20					
	25					
	30					
	35					

DATE STARTED: 7-26-96	GWL: DEPTH: -- DATE/TIME: --	NOTES:
DATE COMPLETED: 7-26-96	GWL: DEPTH: -- DATE/TIME: --	DRILL RIG: Track mounted SIMCO
FIELD GEOLOGIST: RAS	DRILLING METHOD: 3-7/8" water rotary,	DRILLER: Todd England
CHECKED BY: JZD/RAS	continuous split spoon sampling (0.0' - 13.5')	* penetrometer (tons per square foot)
DRILLING CO.: CTL Drilling		

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B3A-1B

COORDINATES
N 699701.50 E 1999938.33

SURFACE EL: 895.10

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	DESCRIPTION	USCS SYMBOL	REMARKS
890.00	5		No samples 0' to 10' See log for B3A-1A		
	10		Top of Undisturbed Soil 10.0'		
		S-1 15 4	Clayey silt, dark brown, organic, soft to medium stiff, moist to wet	ml/cl	*0.75, 0.5, 0.25 bottom
		S-2 19 3	Same as above, soft, wet, organic material, wood fragment 14.0'	ml/cl	*0.0 top, 0.5 bottom
880.00	15	S-3 14 5	Silty clay, trace fine sand, dark brown to greenish-gray, m. stiff to stiff, blocky nature, moist (Till)	ml/cl	*1.0 throughout sample
		S-4 18 7	Silty clay, greenish gray and brown mottled, soft to medium stiff, blocky nature, moist to wet (Till)	ml/cl	*0.5, 0.25, 1.5 bottom
875.10	20	S-5 17 7	Silt, trace to some clay, brown and gray mottled, medium stiff to stiff, wet 20.0'	ml	*1.0, 1.0, 0.75 bottom Clay content increases towards 20.0', faint laminations/varves
			BOTTOM OF BORING AT 20.0'		
	25				
	30				
	35				

DATE STARTED: 7-31-96
DATE COMPLETED: 7-31-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: – DATE/TIME: –
GWL: DEPTH: – DATE/TIME: –
DRILLING METHOD: 4-1/4" Hollow Stem Augers (0.0' - 10.0')
3-7/8" water rotary, continuous split spoon sampling (10.0' - 20.0')

NOTES:
DRILL RIG: CME 75
DRILLER: Chris
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B3A-2A

COORDINATES
N 699703.65 E 1999924.29

SURFACE EL: 894.88

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
				Boring drilled to 10.0' below ground surface without sampling. Refer to B3A-2B boring log for subsurface details.		
890.00	5					
884.88	10			BOTTOM OF BORING AT 10.0'		
	15					
	20					
	25					
	30					
	35					

DATE STARTED: 7-31-96
DATE COMPLETED: 8-1-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: -- DATE/TIME: --
GWL: DEPTH: -- DATE/TIME: --
DRILLING METHOD: 4-1/4" I.D. Hollow Stem Augers, no sampling (0.0'-10.0')

NOTES:
DRILL RIG: CME 75
DRILLER: Chris
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590

SITE: Buckeye Lake

LOG OF BORING NO. B3A-2B

COORDINATES
N 699708.77 E 1999929.04

SURFACE EL: 894.95

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 8 4		Silty clay, some sand, gravel and rock fragments, dark gray and brown, medium stiff, dry to moist (Fill)	cl	1st 6" - non cohesive soil and rock; cement blocks underlying topsoil beginning @ 6" bgs.
		S-2 10 4		Silty clay, trace to some sand and rock fragments, brown, orange, and gray mottled, medium stiff to stiff, moist	cl	*0.5, 0.25, 1.25 bottom
890.00	5	S-3 12 6		Same as above, dry to moist	cl	*1.75, 2.0 bottom
		S-4 15 9		Same as above, moist 10.0'	cl	*0.5, 1.25, 2.25 bottom
		S-5 22 10		Silty clay, trace sand, green-gray to dark brown, mottled, stiff to hard,moist (Till)	cl	*4.25, 3.25, 1.25 bottom
	10	S-6 20 6		Same as above, trace to some silt, moist to wet	cl	*0.0, 0.75, 0.5 bottom
		S-7 12 6		Same as above, gray, moist 13.0'	cl	*0.0, 0.0, 1.0 bottom
880.00	15	ST-8 15 N/A		Clayey silt, trace fine sand, dark brown, very stiff, moist Shelby Tube 16.0'		*2.75
		S-9 21 5		Sandy clay, trace to some silt, trace sand, gray and brown mottled, soft, moist to wet (Till)	cl	*0.25 throughout sample
874.95	20	S-10 12 6		Same as above, decrease in silt content, moist to wet, faint laminations 20.0'	cl	*0.5, 1.25, 1.25 bottom
				BOTTOM OF BORING AT 20.0'		
	25					
	30					
	35					

DATE STARTED: 7-31-96
DATE COMPLETED: 8-1-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: -- DATE/TIME: --
GWL: DEPTH: -- DATE/TIME: --
DRILLING METHOD: 4-1/4" I.D. Hollow Stem Augers
continuous split spoon sampling (0.0'-20.0')

NOTES:
DRILL RIG: CME 75
DRILLER: Chris
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B3A-3

COORDINATES
N 699718.40 E 1999904.68

SURFACE EL: 891.55

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
890.00		S-1 9 7		Silty clay, some sand and gravel, brown, very stiff, dry (Fill)	ml/cl	*3.0
		S-2 10 13		Gravel and rock fragments, some sand, silt and clay, brown, moist to wet, water may be drilling water	gm	
	5	S-3 11 100/2		Same as above, wet, water may be drilling water 6.0'	gm	Large sandstone block/rock at
		S-4 14 11		Silt and clay, trace to some sand and gravel, orange brown to dark gray, stiff to very stiff, moist (Till)	ml/cl	*1.75, 2.57 bottom
		S-5 19 11		Sand and gravel, trace silt and clay, br., med. dense, wet 9.0'		
	10			Sandy, organic, silty clay, dark brown to black, soft to very stiff, moist	ml/cl	*2.0, 0.5 bottom
880.00		S-6 16 9		Same as above, stiff to very stiff, moist 12.0'	ml	*2.0, 1.25, 1.25 bottom
877.55		S-7 14 5		Sandy clay, some silt, brown, stiff to very stiff, moist to wet 14.0'	ml/sc	*1.75, 1.5, 1.0 bottom
	15			BOTTOM OF BORING AT 14.0'		
	20					
	25					
	30					
	35					

DATE STARTED: 8-1-96
DATE COMPLETED: 8-1-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: – DATE/TIME: –
GWL: DEPTH: – DATE/TIME: –
DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' - 14.0')

NOTES:
DRILL RIG: CME 75
DRILLER: Chris
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B4A-1A

COORDINATES
N 700649.39 E 2000766.55

SURFACE EL: 893.88

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
890.00	0–10			Boring drilled to 10.0' below ground surface without sampling. Refer to B4A-1B boring log for subsurface details.		
883.88	10			BOTTOM OF BORING AT 10.0'		

Depth scale: 5, 10, 15, 20, 25, 30, 35

DATE STARTED: 8-2-96
DATE COMPLETED: 8-2-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: -- DATE/TIME: --
GWL: DEPTH: -- DATE/TIME: --
DRILLING METHOD: 3-7/8" water rotary, no sampling (0.0' - 10.0')

NOTES:
DRILL RIG: CME 75
DRILLER: Chris
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590

SITE: Buckeye Lake

LOG OF BORING NO. B4A-1B

COORDINATES
N 700645.59 E 2000761.90

SURFACE EL: 894.04

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 14 18		Silty clay, trace to some sand and gravel, dark brown, very stiff to hard, dry (Fill)	ml/cl	*4.5+, 3.5 bottom
				2.5'	ml	*3.5, 1.25 bottom
		S-2 12 9		Sand, trace to some silt, trace clay, brown, loose, moist (Fill)	sp	
890.00				4.5'	sp	
	5	S-3 14 12		Clayey silt, trace to some sand, orange brown and gray, very stiff, moist (Fill)	ml	*0.5, 3.75 2.5 bottom
		S-4 14 6		Clayey silt, trace to some rock fragments and sand, dark gray and brown, soft, moist to wet (Fill) 8.0'	ml	*0.0, 0.0, 0.25 bottom
		S-5 17 4		Silty clay/clayey silt, trace sand, greenish gray and dark gray mottled, soft to medium stiff, moist (Till)	ml/cl	*0.25, 0.5, 0.5 bottom
	10	S-6 14 5		Same as above, more silt and fine sand, dark gray, mottles diminish, moist to wet	ml/cl	*0.75, 0.5, 0.25 bottom
		ST-7 19		Shelby Tube		Driller reports loss of drilling water down borehole
880.00						
	15	S-8 14 3		Silty clay, trace sand, green-gray and dark gray mottled, very soft, moist to wet	ml	*0.0, 0.0, 0.25 bottom
		S-9 17 6		Same as above, increase in clay content, soft to stiff, wet	ml/cl	*1.0, 1.5, 0.5 bottom
		S-10 17 5		Same as above, green-gray and medium gray mottles, soft to stiff, moist to wet	ml	*0.0, 1.5, 0.5 bottom
874.04	20			20.0'		
				BOTTOM OF BORING AT 20.0'		
	25					
	30					
	35					

DATE STARTED: 8-2-96	GWL: DEPTH: -- DATE/TIME: --	NOTES:
DATE COMPLETED: 8-2-96	GWL: DEPTH: -- DATE/TIME: --	DRILL RIG: CME 75
FIELD GEOLOGIST: JZD	DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' - 20.0')	DRILLER: Chris
CHECKED BY: RAS		* penetrometer (tons per square foot)
DRILLING CO.: CTL Drilling		

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B4A-2

COORDINATES
N 700662.16 E 2000756.47

SURFACE EL: 893.42

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 14 18		Silty clay, trace to some rock fragments and sand, dark gray and brown, very stiff to hard, dry (Fill)	ml/cl	*4.5+, 3.5, 4.5+ bottom
890.00		S-2 15 7		Clay, trace to some silt, trace sand and rock fragments, brown and gray, very stiff to hard, dry to moist (Fill)	cl	*4.0, 2.5, 3.5 bottom
	5	S-3 12 13		Silty clay, trace sand and rock fragments, orange brown and gray, very stiff, dry to moist (Fill)	ml/cl	*2.0, 3.75, 2.25 bottom
		S-4		Shelby tube - no recovery 8.0'		
		ST-5 24 N/A		Shelby tube		
881.42	10	S-6 16 23		Clay, some silt, orange brown and gray mottled, very stiff, moist (Till) 12.0'	cl	*3.0, 3.0, 3.5 bottom
				BOTTOM OF BORING AT 12.0'		
	15					
	20					
	25					
	30					
	35					

DATE STARTED: 8-2-96
DATE COMPLETED: 8-2-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: – DATE/TIME: –
GWL: DEPTH: – DATE/TIME: –
DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' - 12.0')

NOTES:
DRILL RIG: CME 75
DRILLER: Chris
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B4A-3

COORDINATES N 700674.21 E 2000747.00

SURFACE EL: 890.86

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
890.00		S-1 15 12		Clay, some silt and sand, brown, very stiff, dry (Fill)	cl	*3.25, 3.25, 2.0 bottom
		S-2 7 5		Clayey silt, some sand, very stiff, brown, moist (Fill)	ml	*2.0, 2.5 bottom
	5	S-3 12 4		Same as above, moist 5.0'	ml/ sm	*2.5, 3.25, 3.0 bottom Driller reports loss of drilling water
				Silty clay, trace fine sand, orange brown and gray mottles, very stiff, moist (Till)		
		S-4 17 15		Same as above, moist	ml/ sm	*3.0, 3.25, 2.5 bottom
		S-5 12 17		Clayey silt, trace to some sand, trace organic material, dark brown to dark gray, very stiff, moist	ml	*2.0, 2.25 bottom
880.00	10	S-6 16 9		Silty clay, trace fine sand, green-gray and medium gray mottles, medium stiff to stiff, moist to wet	ml	*1.5, 0.5, 1.0 bottom
876.86		S-7 16 6		Silty clay, trace to some sand, orange brown to dark gray mottled, medium stiff to stiff, moist 14.0'	ml/ cl	*1.0, 0.5, 0.75 bottom
	15			BOTTOM OF BORING AT 14.0'		
	20					
	25					
	30					
	35					

DATE STARTED: 8-5-96
DATE COMPLETED: 8-5-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: -- DATE/TIME: --
GWL: DEPTH: -- DATE/TIME: --
DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' - 14.0')

NOTES:
DRILL RIG: CME 75
DRILLER: Chris
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B5A-1A

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	COORDINATES N 702724.48 E 2004702.80 SURFACE EL: 895.19 DESCRIPTION	USCS SYMBOL	REMARKS
				Boring drilled to 10.0' below ground surface without sampling. Refer to B5A-1B boring log for subsurface details.		
890.00	5					
885.19	10			BOTTOM OF BORING AT 10.0'		
	15					
	20					
	25					
	30					
	35					

DATE STARTED: 7-24-96
DATE COMPLETED: 7-24-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: -- DATE/TIME: --
GWL: DEPTH: -- DATE/TIME: --
DRILLING METHOD: 3-7/8" water rotary, no sampling (0.0' - 10.0')

NOTES:
DRILL RIG: Track mounted SIMCO
DRILLER: Todd England
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B5A-1B

COORDINATES
N 702721.53 E 2004705.08

SURFACE EL: 894.95

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 14 12		Silty sand, some clay, trace gravel, brown, medium stiff to stiff, dry (Fill)	sm	*.75 top, 0.0 bottom
		S-2 9 9		Same as above, increase in fine gravel content 4.0'	sm	*0.0 throughout sample
890.00	5	S-3 11 6		Clayey silt, trace to some sand, dark brown, very soft to soft, moist (Fill) 6.0'	ml	*0.5 throughout sample
		S-4 5 16		Silty clay, trace fine sand, orange-brown, very stiff, moist (Till)	ml	*2.5 middle
		S-5 11 8		Same as above, dark gray, soft to stiff, moist	ml/cl	*0.5 top, 1.0 bottom
	10	S-6 22 8		Clay, trace silt, dark gray, stiff, blocky texture, moist (Till)	cl	*1.0 top, 1.25 bottom
		S-7 15 5		Same as above, interbedded 3" clayey silt seam, wet	cl	*0.75 throughout sample
880.00	15	S-8 12 4		Clay, trace to some silt, dark gray, very soft, wet	cl	*0.0 throughout sample
		S-9 12 10		Clayey silt, trace fine gravel, red-brown, very stiff, dry 18.0'	ml	*3.25 top, 2.5 bottom
		S-10 16 10		Sandy silt/silty sand, trace to some clay, brown, very stiff to soft at bottom, wet 20.0'	sm	*2.25 top, 0.5 bottom
874.95	20			BOTTOM OF BORING AT 20.0'		
	25					
	30					
	35					

DATE STARTED: 7-24-96
DATE COMPLETED: 7-24-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: -- DATE/TIME: --
GWL: DEPTH: -- DATE/TIME: --
DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' - 20.0')

NOTES:
DRILL RIG: Track mounted SIMCO
DRILLER: Todd England
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B5A-2

COORDINATES
N 702731.15 E 2004697.22

SURFACE EL: 894.81

ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 12 3		Clayey silt, trace sand and fine to medium gravel, dark brown, stiff, dry (Fill)	ml	*1.25 top, 1.0 bottom
		S-2 8 9		Clayey silt, some sand, yellow-brown, soft to medium stiff, moist (Fill)	ml	*0.75 top, 0.5 bottom
890.00	5	S-3 11 10		Same as above, medium stiff to stiff, moist 6.0'	ml	*0.75 top, 1.25 bottom
		S-4 10 8		Silty clay, trace sand and gravel, mottled orange-brown and gray, blocky texture, very stiff, dry to moist (Till)	ml/cl	*3.75 top, 3.5 bottom
		S-5 9 11		Same as above, slight increase in clay content, dry to moist	ml/cl	*2.25 top, 2.5 bottom
	10	S-6 0 16		No recovery		JZD instructs driller to use better basket
		S-7 8 8		Silty clay, blue-gray, soft, moist (Till)	cl	*0.5 throughout sample
880.00	15	S-8 10 8		Same as above, color change to brown toward 16.0'	cl ml	*1.75 top, 4.5+ bottom
		S-9 9 11		Clay, some silt, dark brown, very stiff, moist (Till)	ml/cl	*2.0 top, 2.5 bottom
		S-10 17 8		Sand, trace silt and clay, gray, loose, wet Clay, some silt, trace gravel, brown, very stiff, dry to moist toward 20.0' 20.0'	sp cl	*0.5 top, 2.25 bottom
874.81	20			BOTTOM OF BORING AT 20.0'		
	25					
	30					
	35					

DATE STARTED: 7-24-96
DATE COMPLETED: 7-24-96
FIELD GEOLOGIST: JZD
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: -- DATE/TIME: --
GWL: DEPTH: -- DATE/TIME: --
DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' - 20.0')

NOTES:
DRILL RIG: Track mounted SIMCO
DRILLER: Todd England
* penetrometer (tons per square foot)

Paul C. Rizzo Associates, Inc.
CONSULTANTS

PROJECT NO.: 95-1590 SITE: Buckeye Lake

LOG OF BORING NO. B5A-3

COORDINATES
N 702744.53 E 2204685.61

SURFACE EL: 886.07

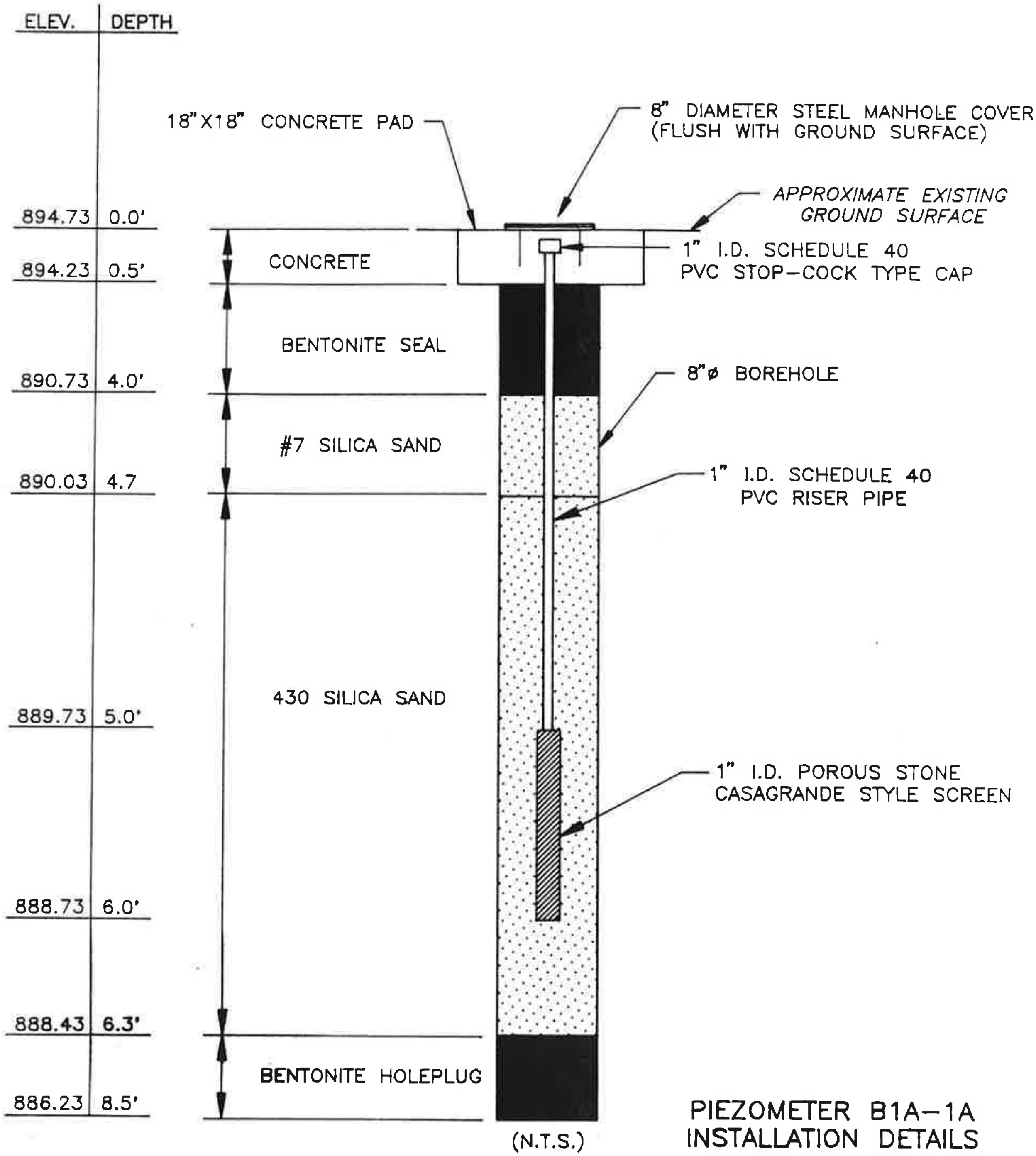
ELEV. (FEET MSL)	DEPTH (FEET)	SAMPLE NO. AND TYPE	PROFILE	DESCRIPTION	USCS SYMBOL	REMARKS
		S-1 8 5		Silty clay, tr. fine sand, rock fragments and roots (clayey topsoil), dark brown to gray, m. stiff to stiff (Fill) 2.0'	ml/ cl	Moist to wet *1.0
		S-2 15 4		Clay, some to trace silt, mottled orange-brown to gray, med stiff, sub-blocky structure, moist to wet (Till)	cl/ ch	Shelby tube attempted from 2.0' to 4.5'. No recovery on Shelby tube, will go in and spoon this interval *0.75
	5	ST-3 28 N/A		Shelby tube 4.5' to 7.0'		*2.5, moist
880.00						
		S-4 6 13		Silty clay, trace fine to coarse sand, orange-brown, very stiff, weak laminations (Till)	cl	Driller mistakenly drilled to 10.0'
				No sample 9.0' to 10.0'		
	10	S-5 14 18		Clayey silt, some coarse sand and gravel, orange-brown, hard, moist (Till)	ml	*4.25 Looks like water-lain till
		ST-6 6 N/A		Shelby tube 12.0' to 14.5' Same as above, orange-brown and gray mottled 14.5'		Could only push 18" only 6" recovery in tube - jarred sample instead
871.57	15			BOTTOM OF BORING AT 14.5'		Boring open to 11.0'
	20					
	25					
	30					
	35					

DATE STARTED: 7-25-96
DATE COMPLETED: 7-25-96
FIELD GEOLOGIST: RAS
CHECKED BY: RAS
DRILLING CO.: CTL Drilling

GWL: DEPTH: – DATE/TIME: –
GWL: DEPTH: – DATE/TIME: –
DRILLING METHOD: 3-7/8" water rotary, continuous split spoon sampling (0.0' - 14.5')

NOTES:
DRILL RIG: Track mounted SIMCO
DRILLER: Todd England
* penetrometer (tons per square foot)

PIEZOMETER CONSTRUCTION DIAGRAMS



PIEZOMETER B1A-1A INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

PREPARED FOR

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CAD FILE NUMBER	95-1590-E100
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LPL	10-1-96
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PLOT	1=1

CAD FILE NUMBER 95-1590-E101

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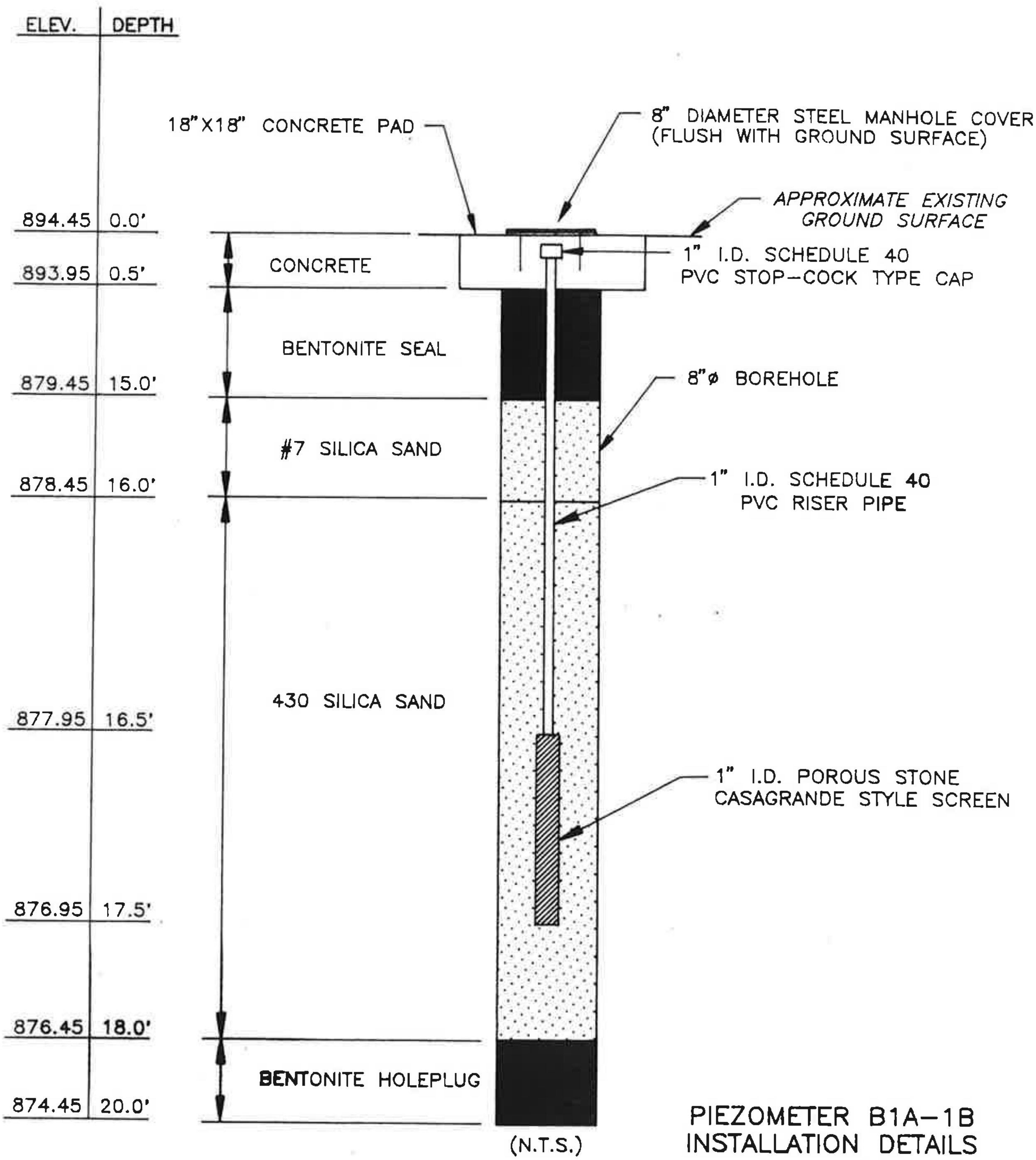

PIEZOMETER B1A-1B INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
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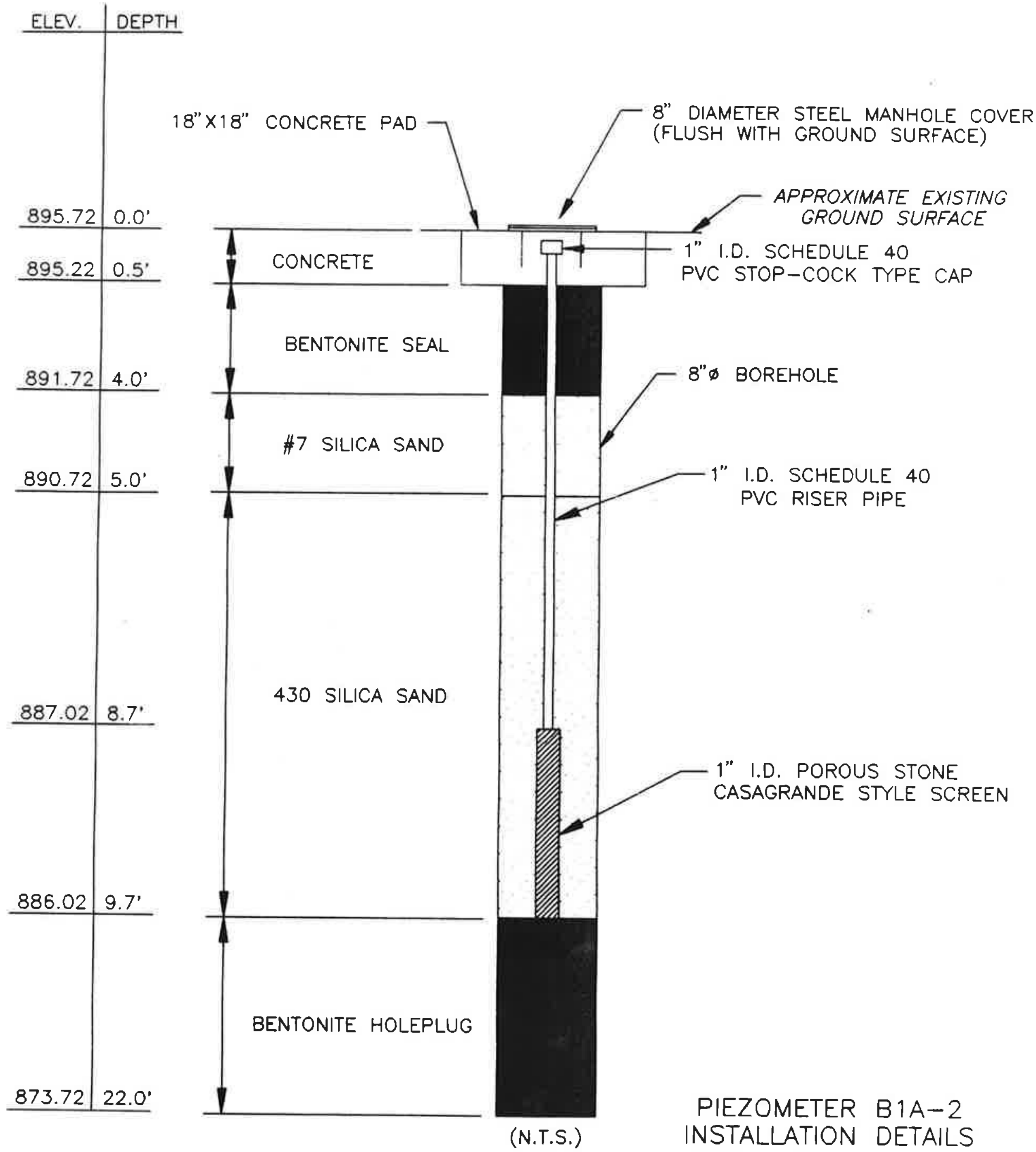

PIEZOMETER B1A-2 INSTALLATION DETAILS

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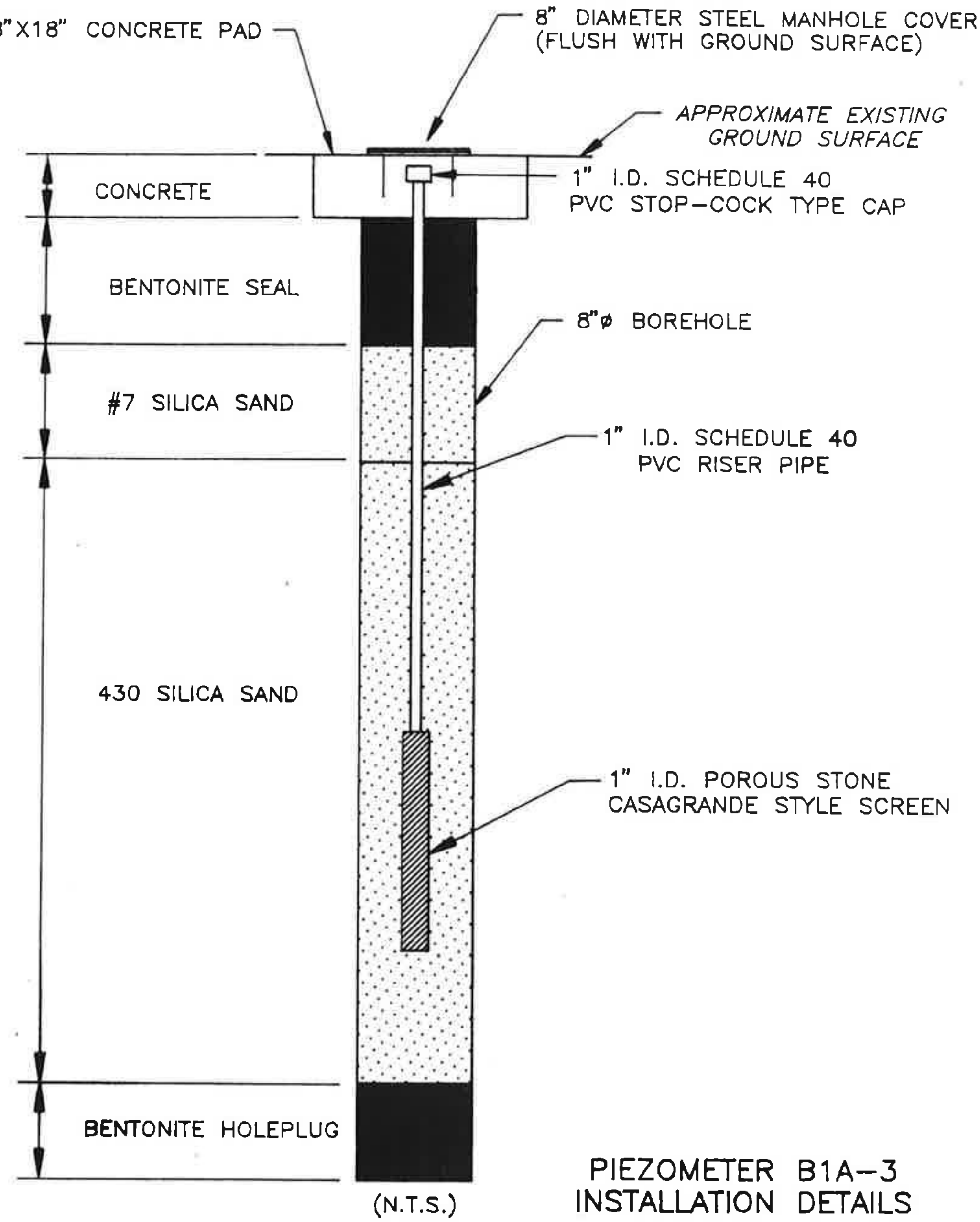
	10-1-96
PLOT	1=1

CAD FILE NUMBER 95-1590-E103

DRAWN BY	LPL	CHECKED BY	APPROVED BY	PLOT
	10-1-96			1=1

ELEV.	DEPTH
890.31	0.0'
889.81	0.5'
886.11	4.2'
885.11	5.2'
884.61	5.7'
883.61	6.7'
883.31	7.0'
879.31	11.0'



PIEZOMETER B1A-3 INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
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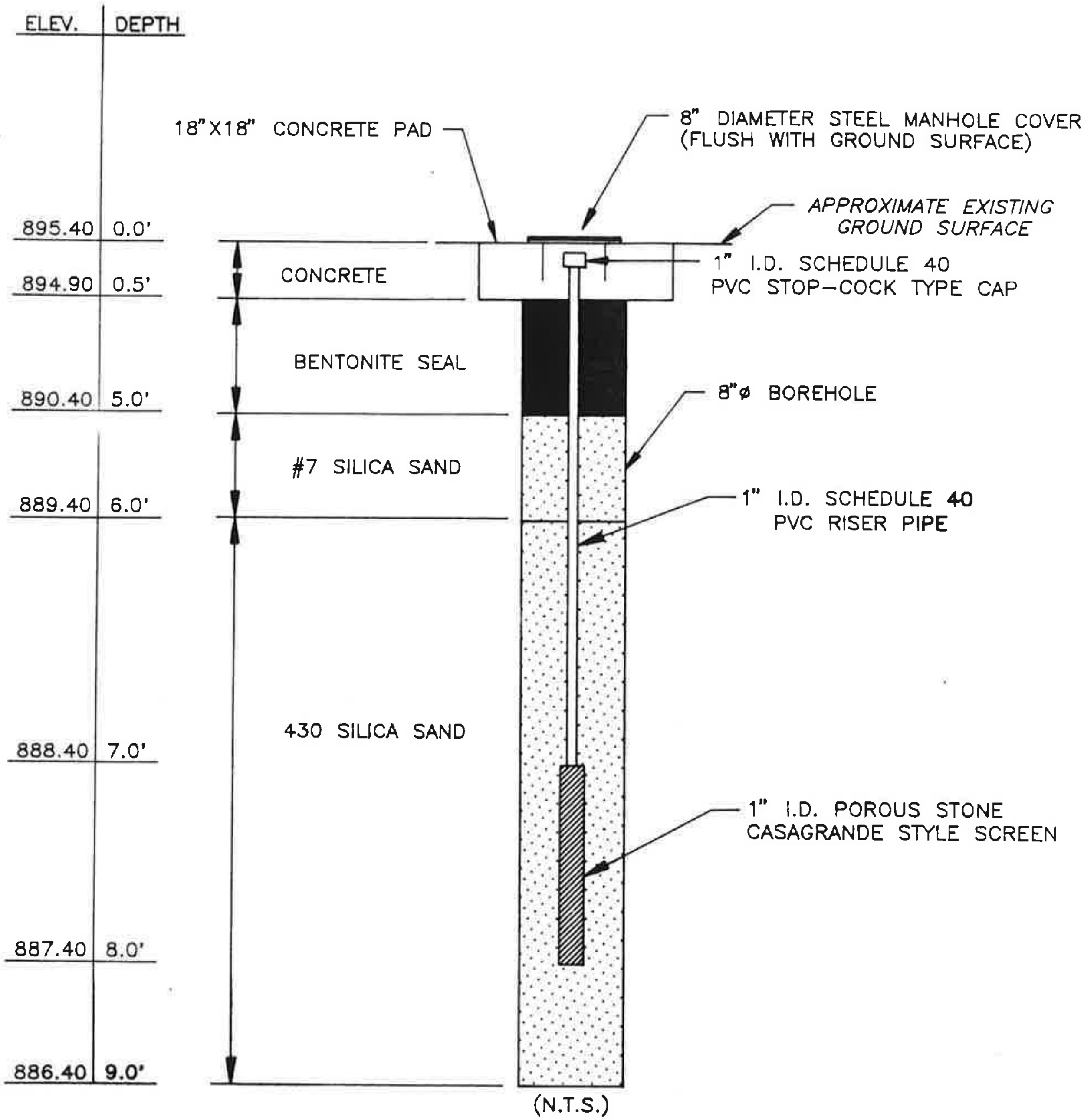

PIEZOMETER B2A-1A
INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
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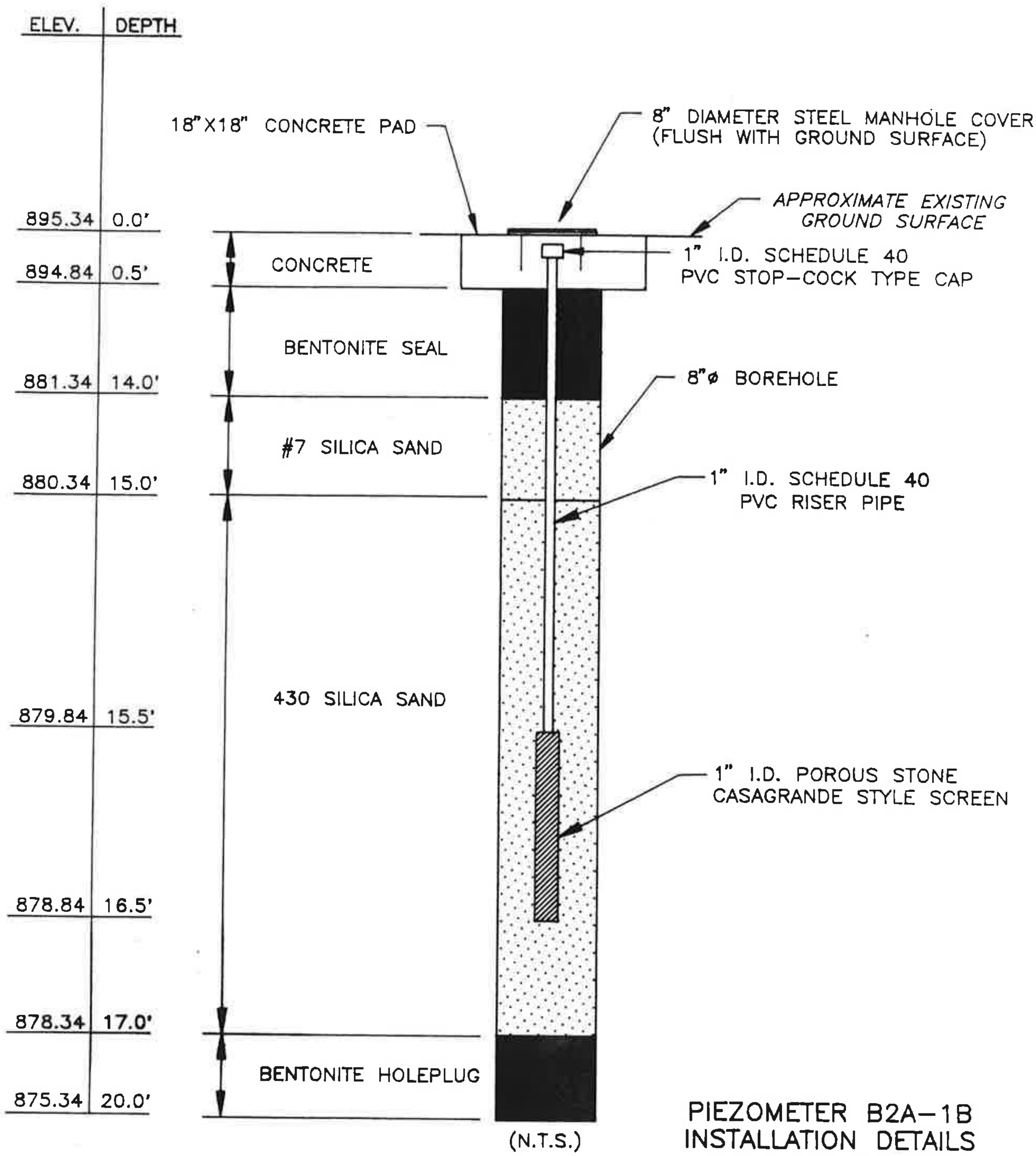
PLOT	1=1



PIEZOMETER B2A-1B INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
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CAD FILE NUMBER 95-1590-E105
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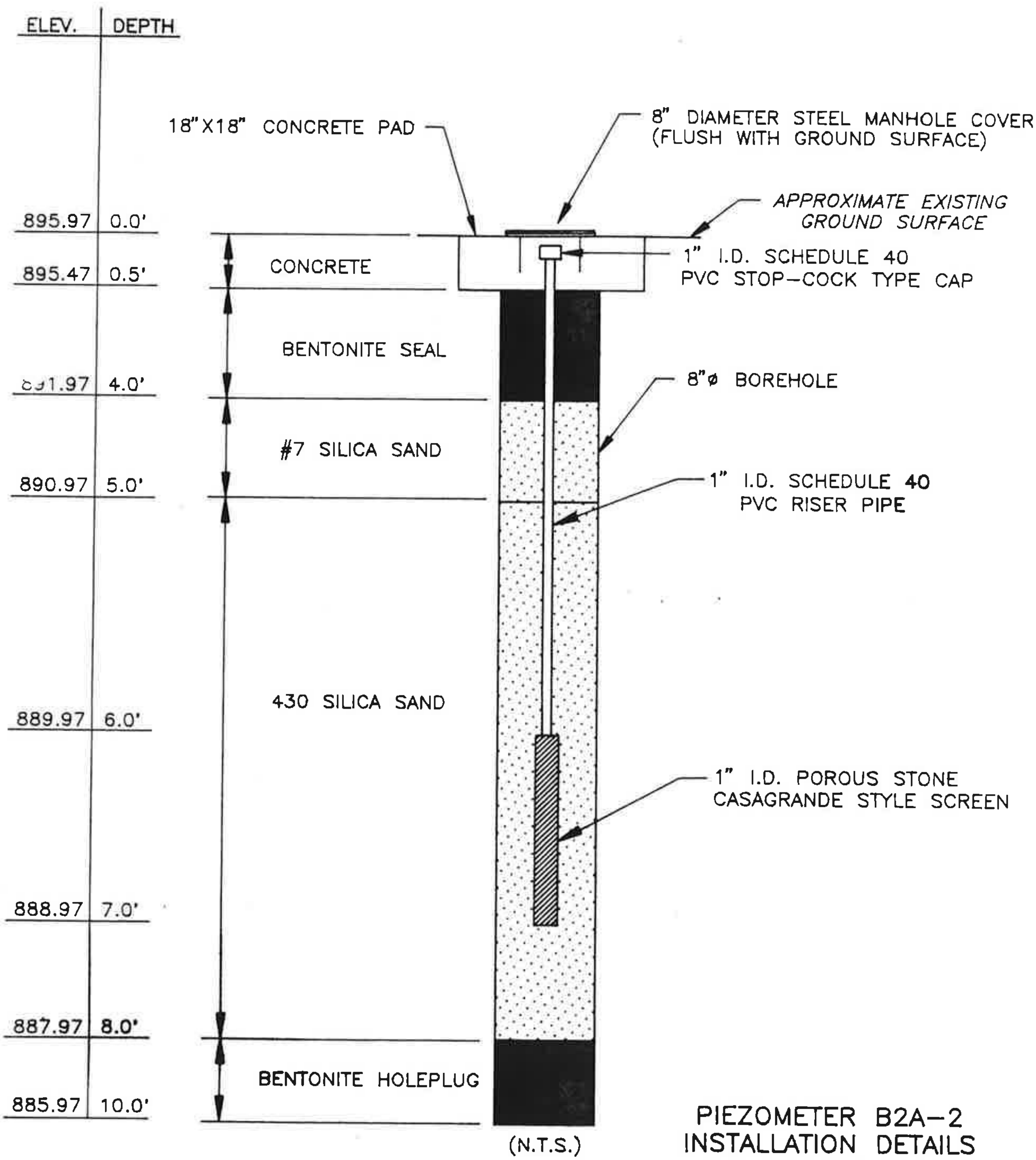

PIEZOMETER B2A-2
INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
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CAD FILE NUMBER 95-1590-E106
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CAD FILE NUMBER 95-1590-E107

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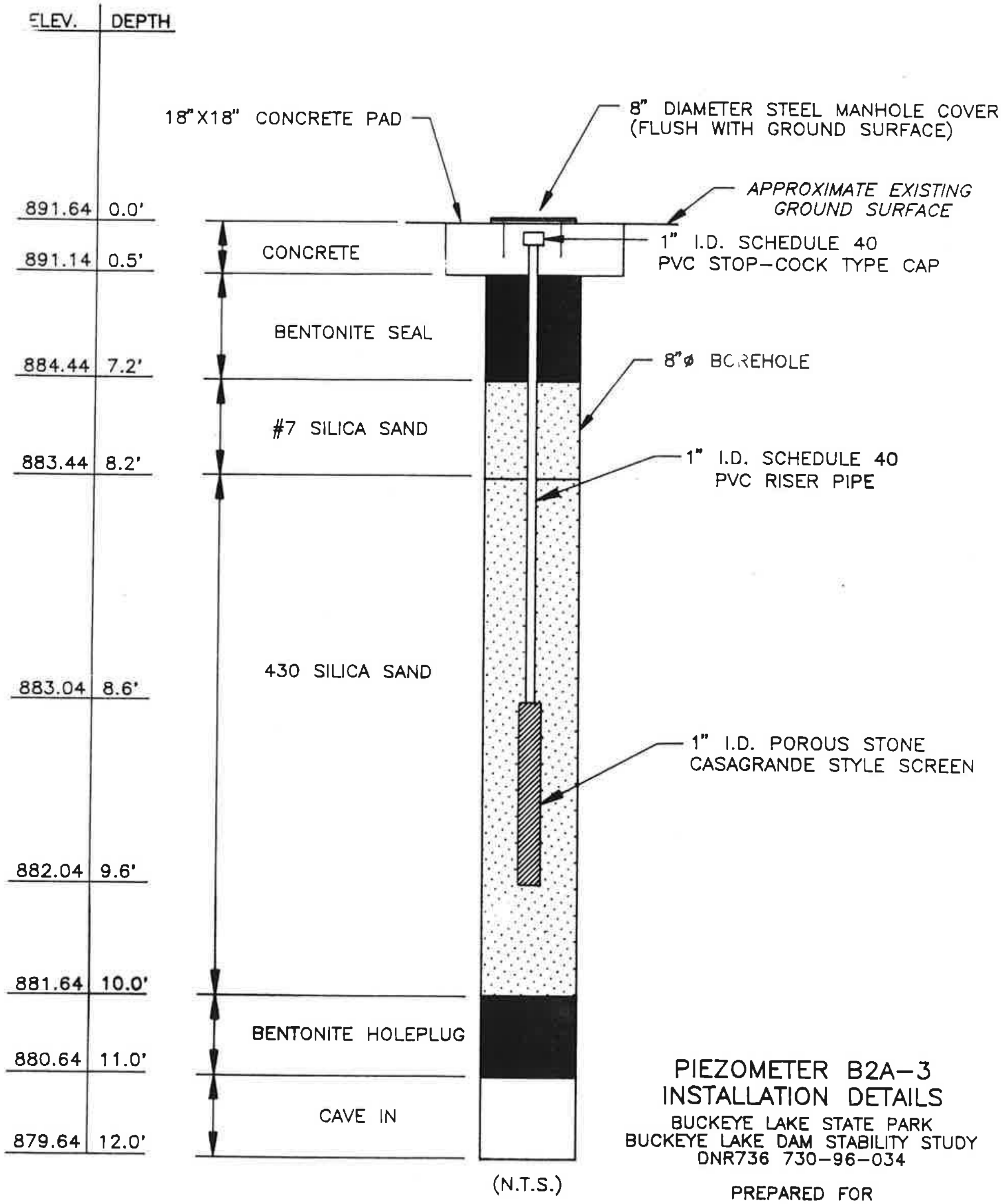
PLOT 1=1



PIEZOMETER B2A-3
INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
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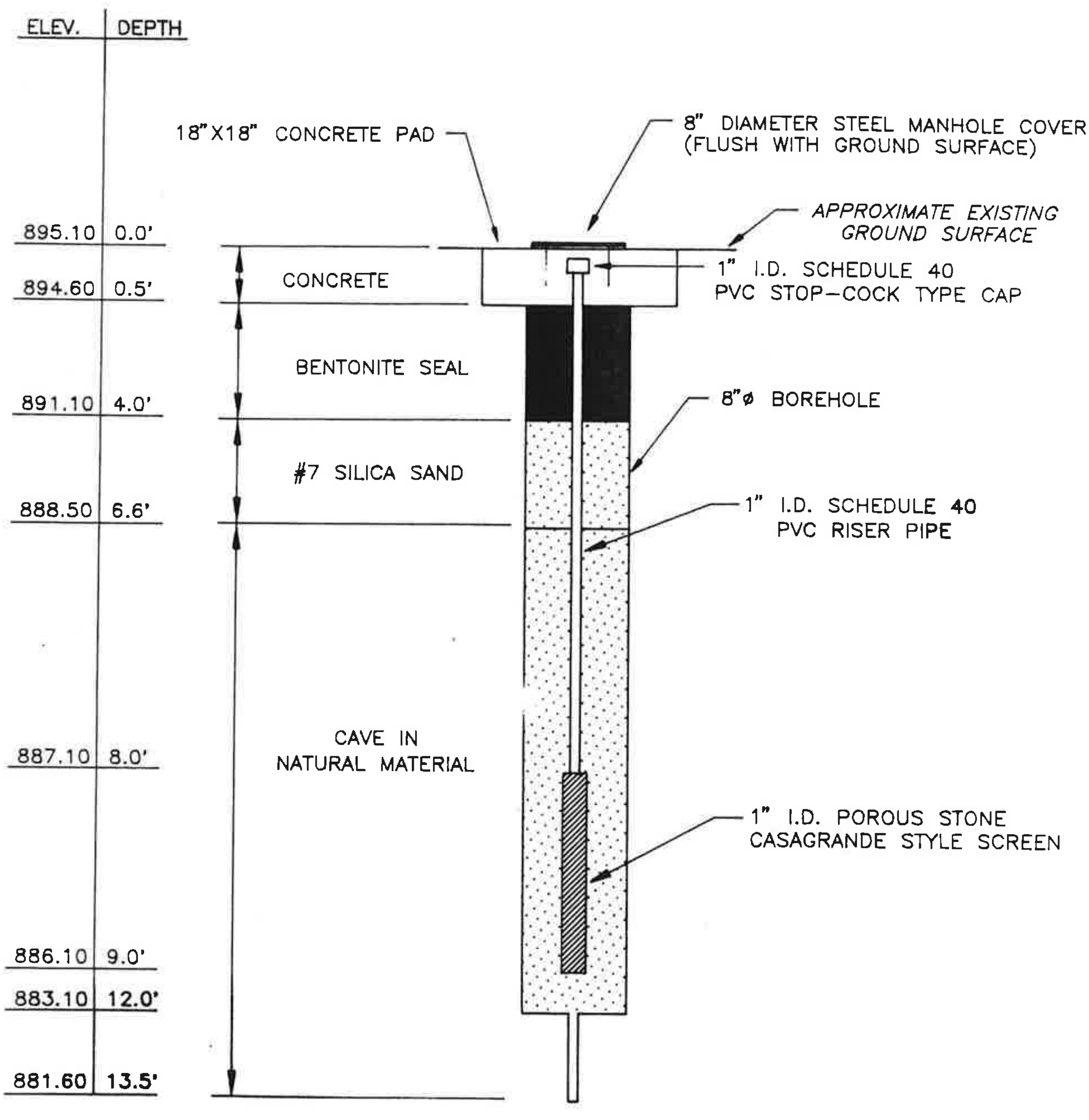

(N.T.S.)

PIEZOMETER B3A-1A INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
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CAD FILE NUMBER 95-1590-E108
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LPL 10-1-96
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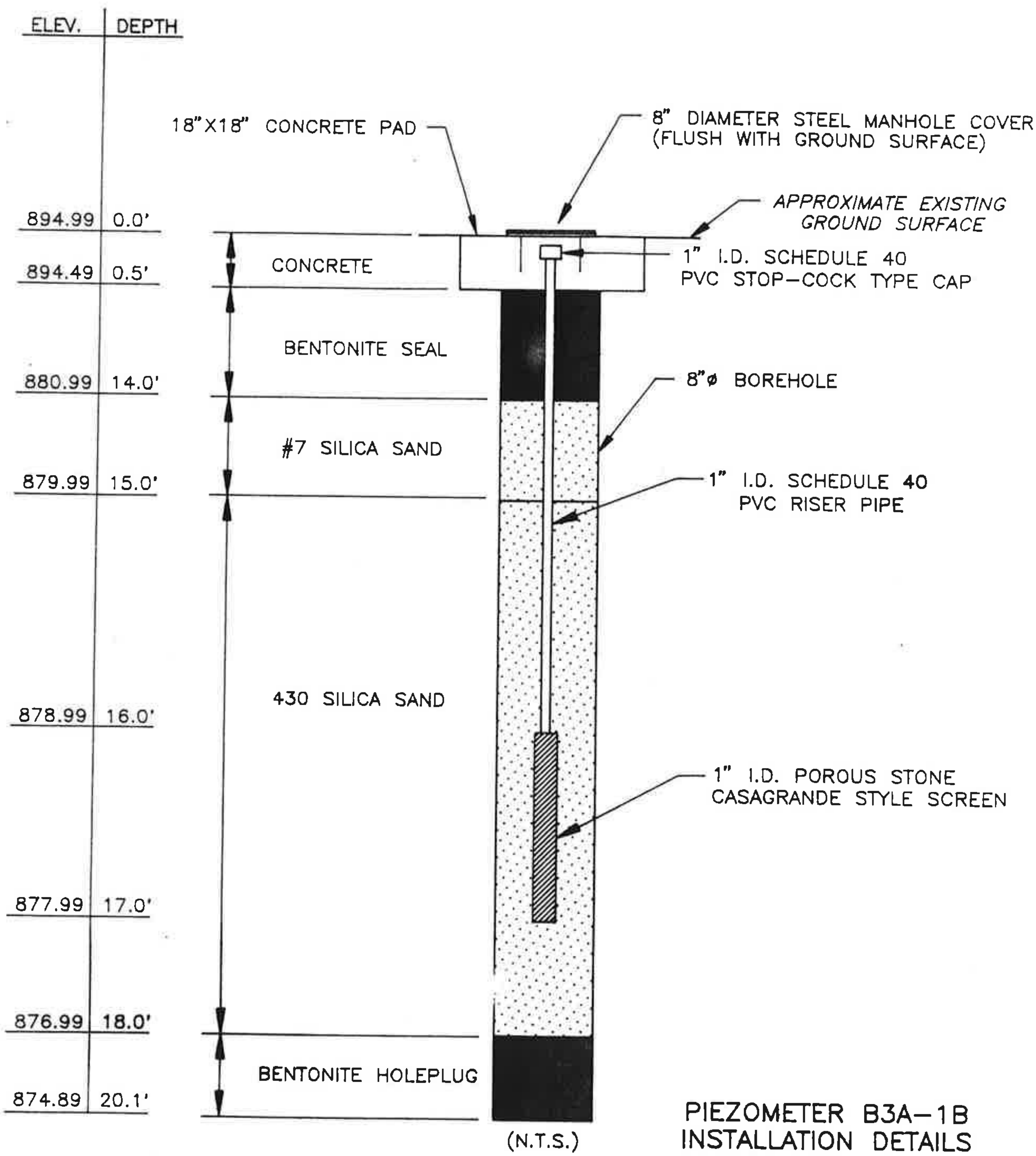
PLOT 1=1



PIEZOMETER B3A-1B INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

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CAD FILE NUMBER 95-1590-E109

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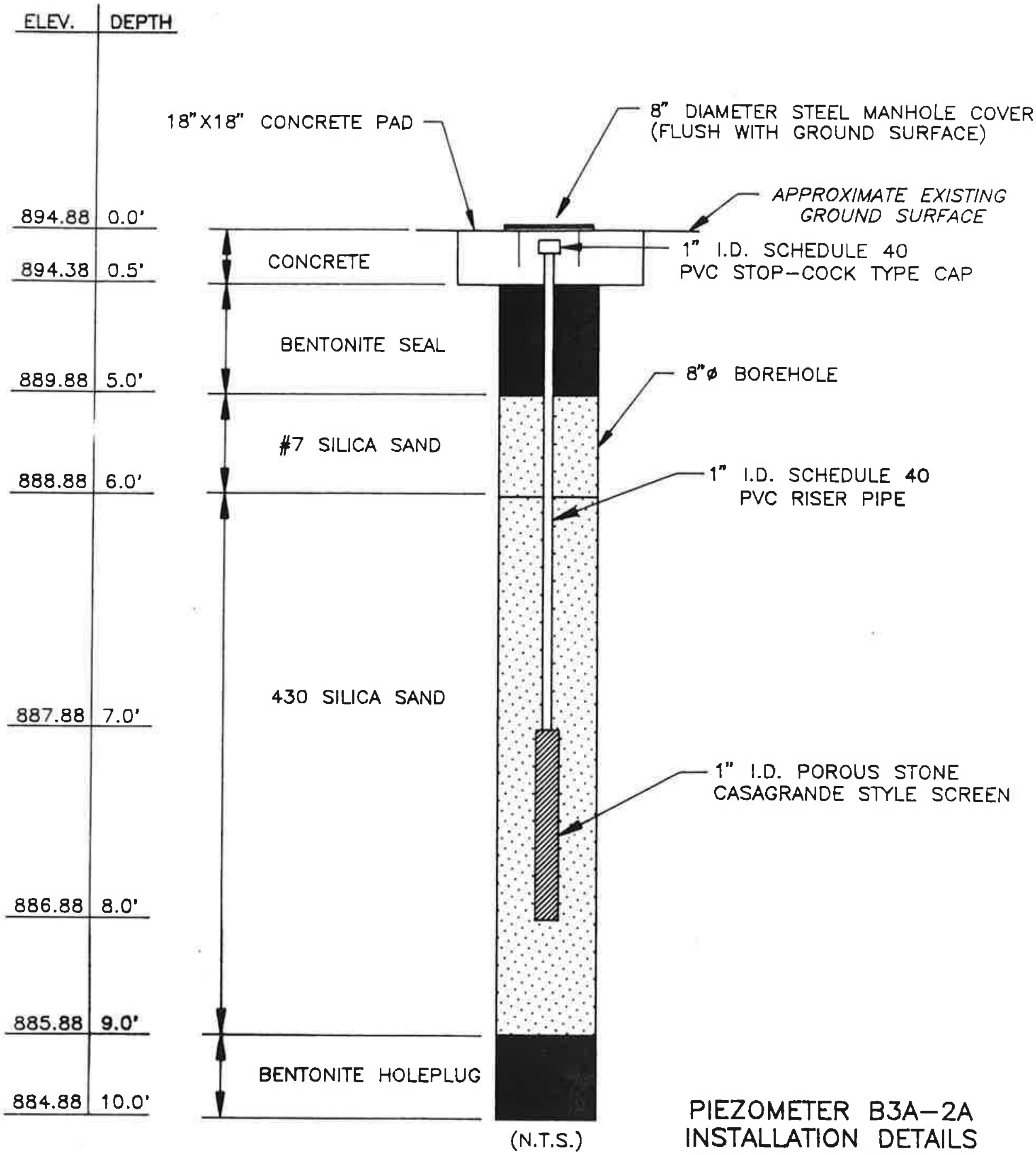
PLOT 1=1



PIEZOMETER B3A-2A INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
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CAD FILE NUMBER	95-1590-E110
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PLOT	1=1

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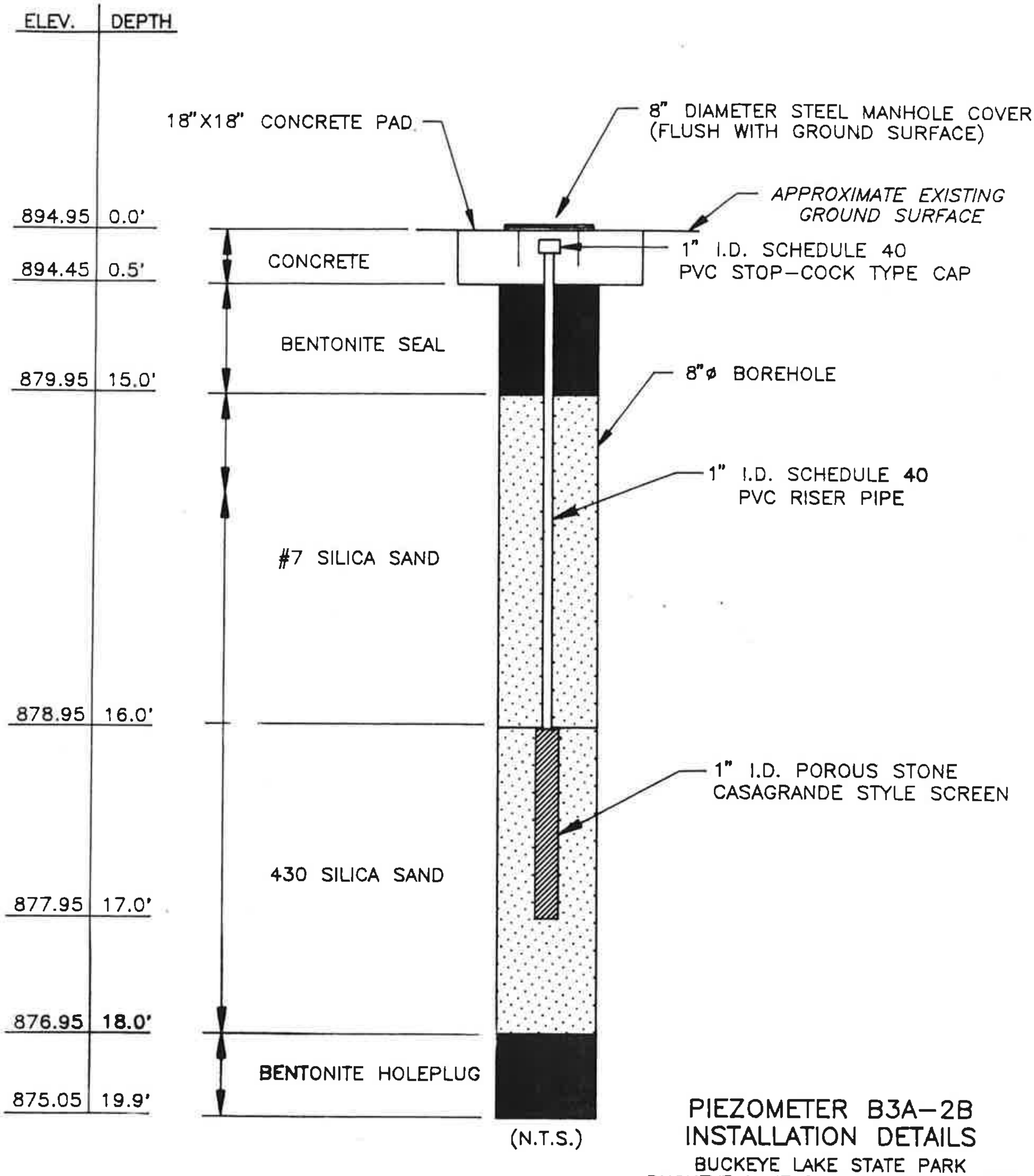

PIEZOMETER B3A-2B INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

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CAD FILE NUMBER 95-1590-E112

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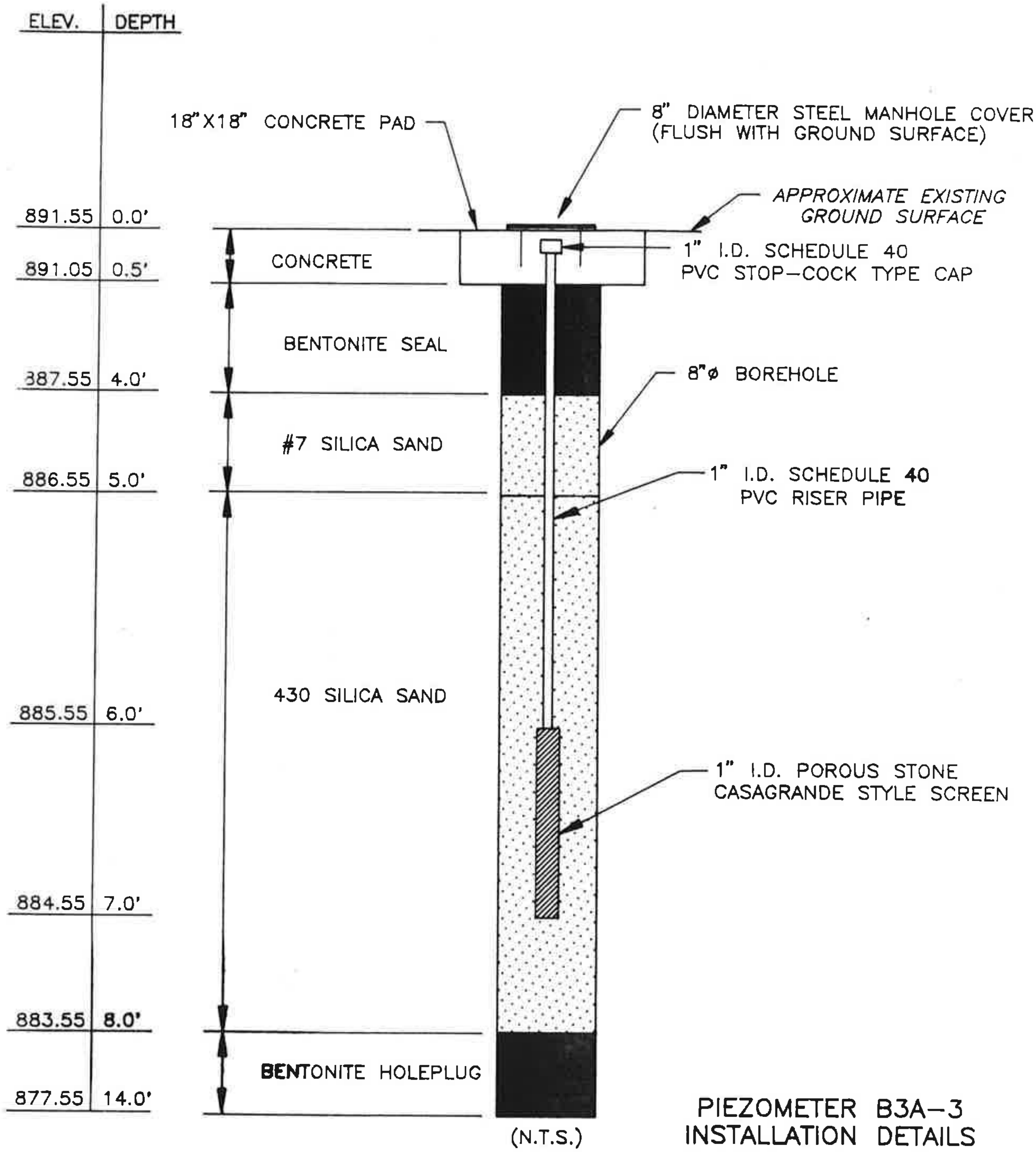

(N.T.S.)

PIEZOMETER B3A-3 INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

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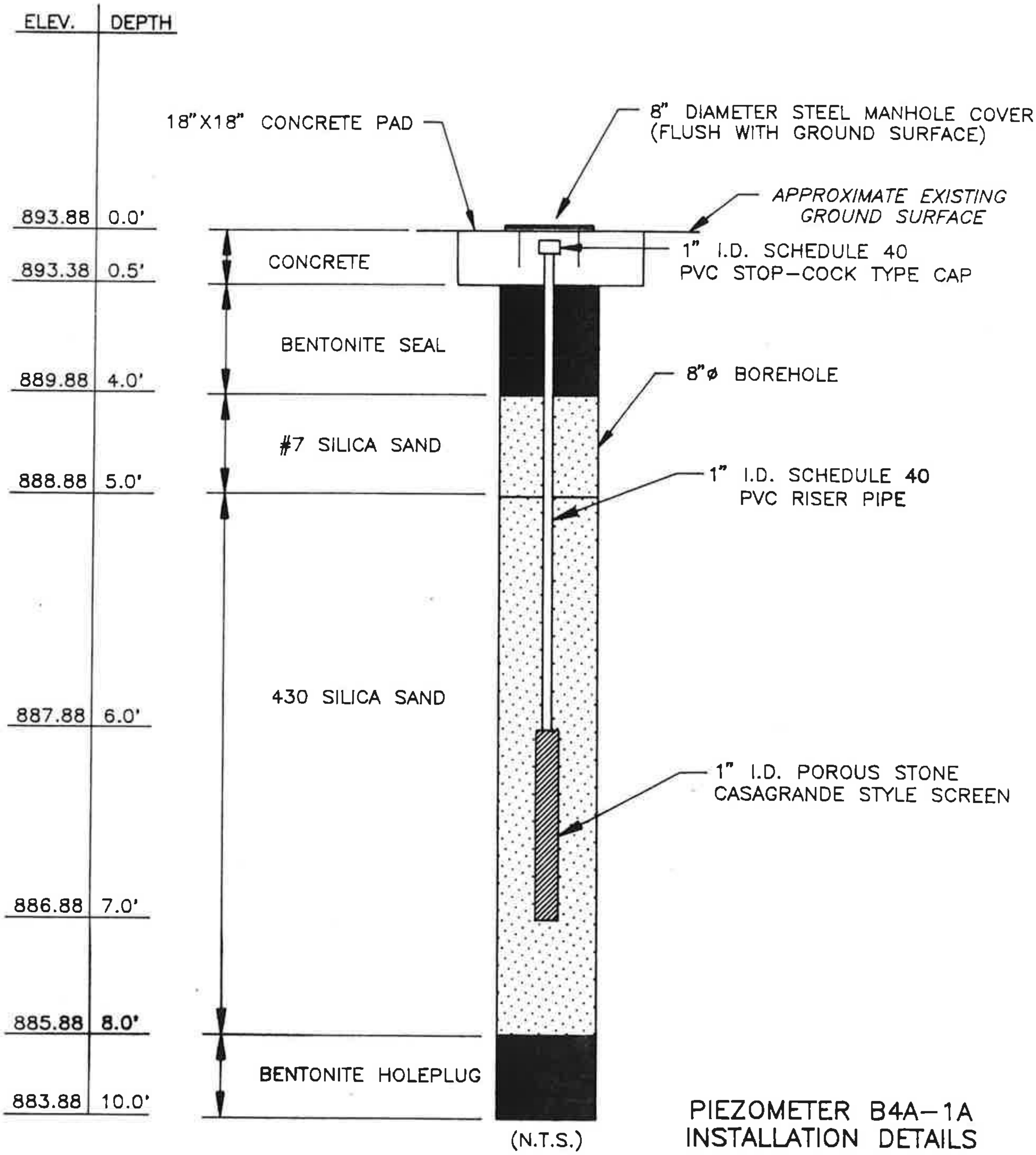

PIEZOMETER B4A-1A INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

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CAD FILE NUMBER	95-1590-E113
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LPL	10-1-96
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PLOT	1=1

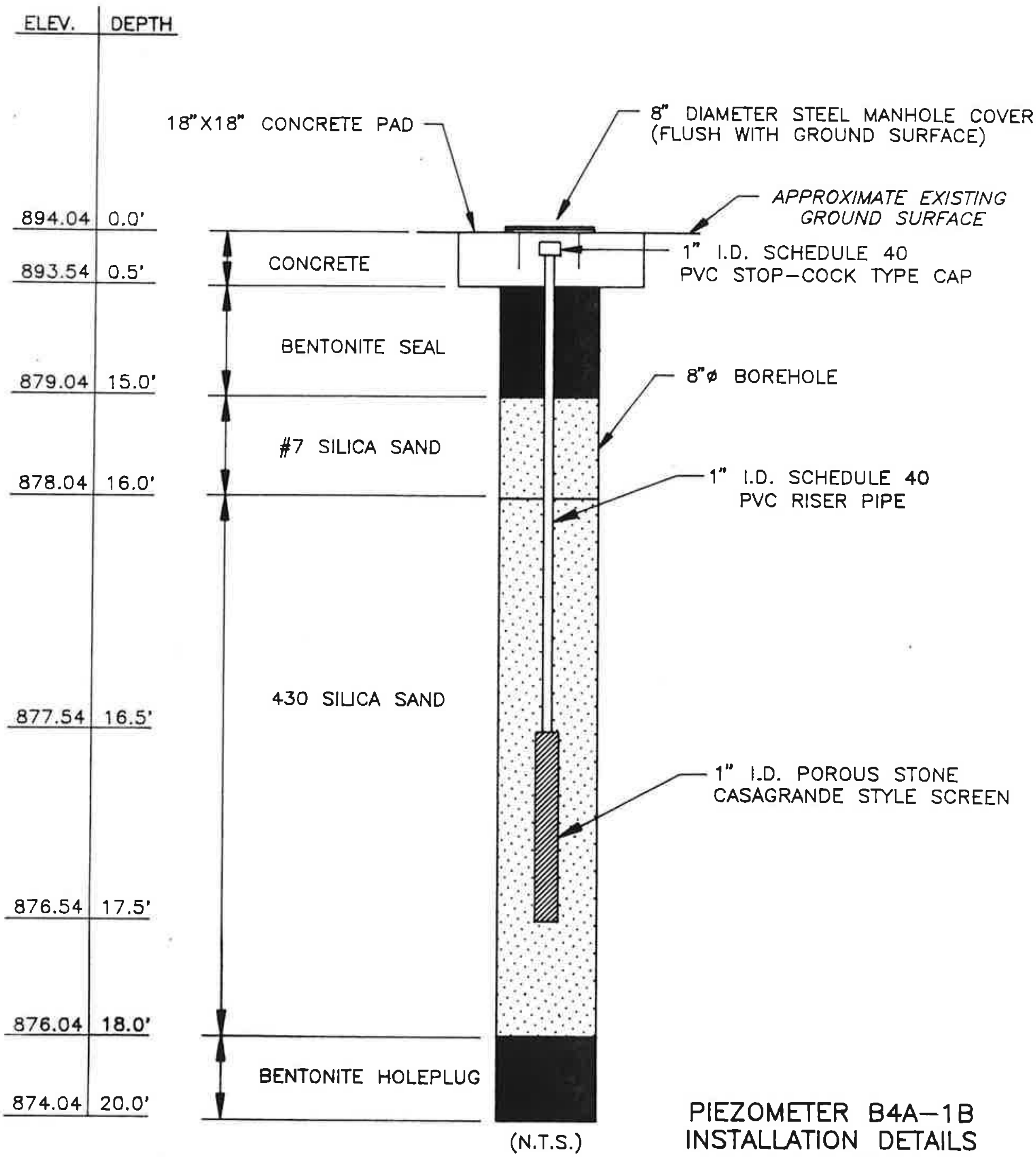
CAD FILE NUMBER 95-1590-E114

CHECKED BY | APPROVED BY

LPL | 10-1-96

DRAWN BY

PLOT 1=1



PIEZOMETER B4A-1B INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

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COLUMBUS, OHIO

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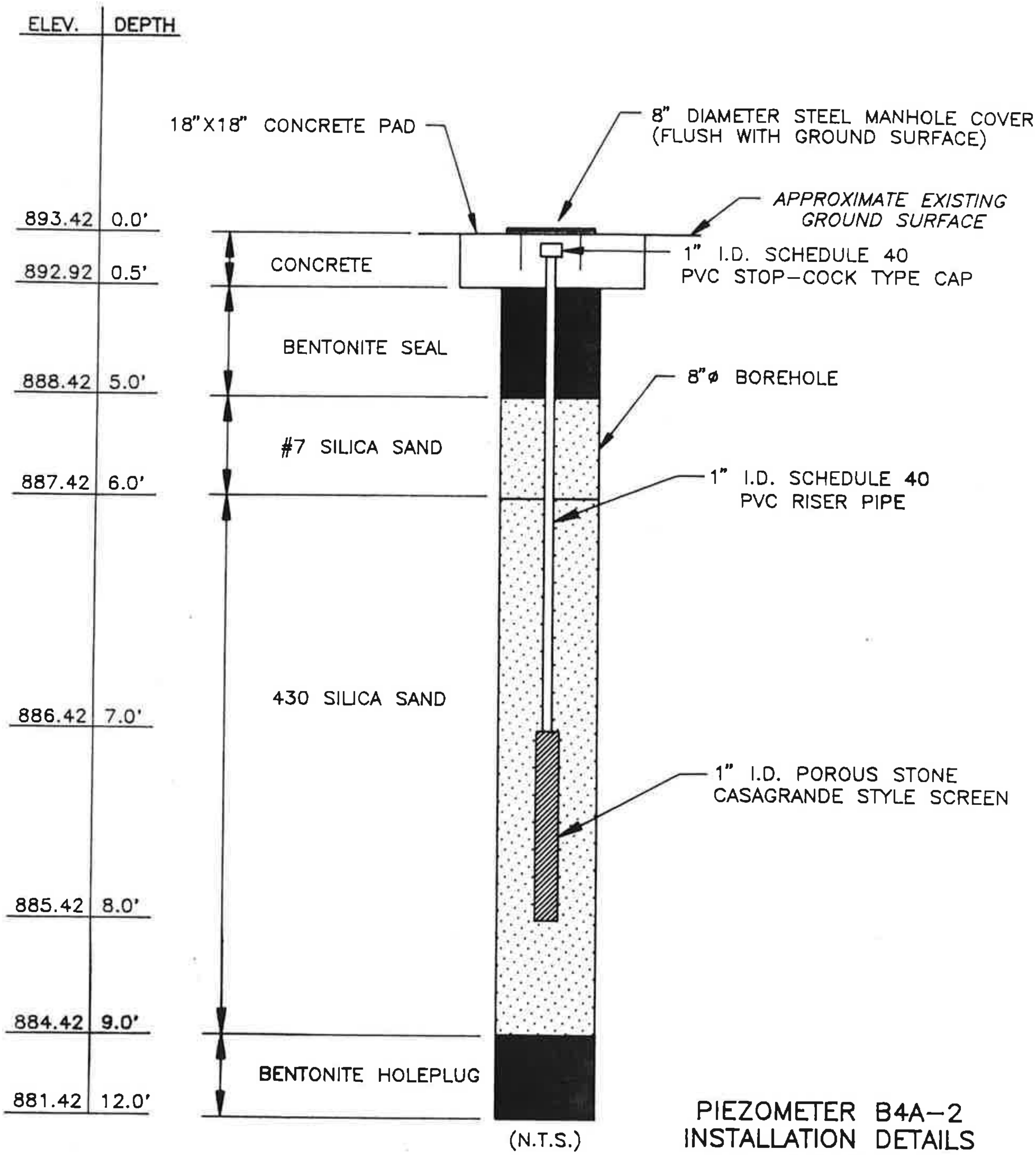

PIEZOMETER B4A-2 INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

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COLUMBUS, OHIO

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CAD FILE NUMBER 95-1590-E115
CHECKED BY
APPROVED BY
LPL
10-1-96
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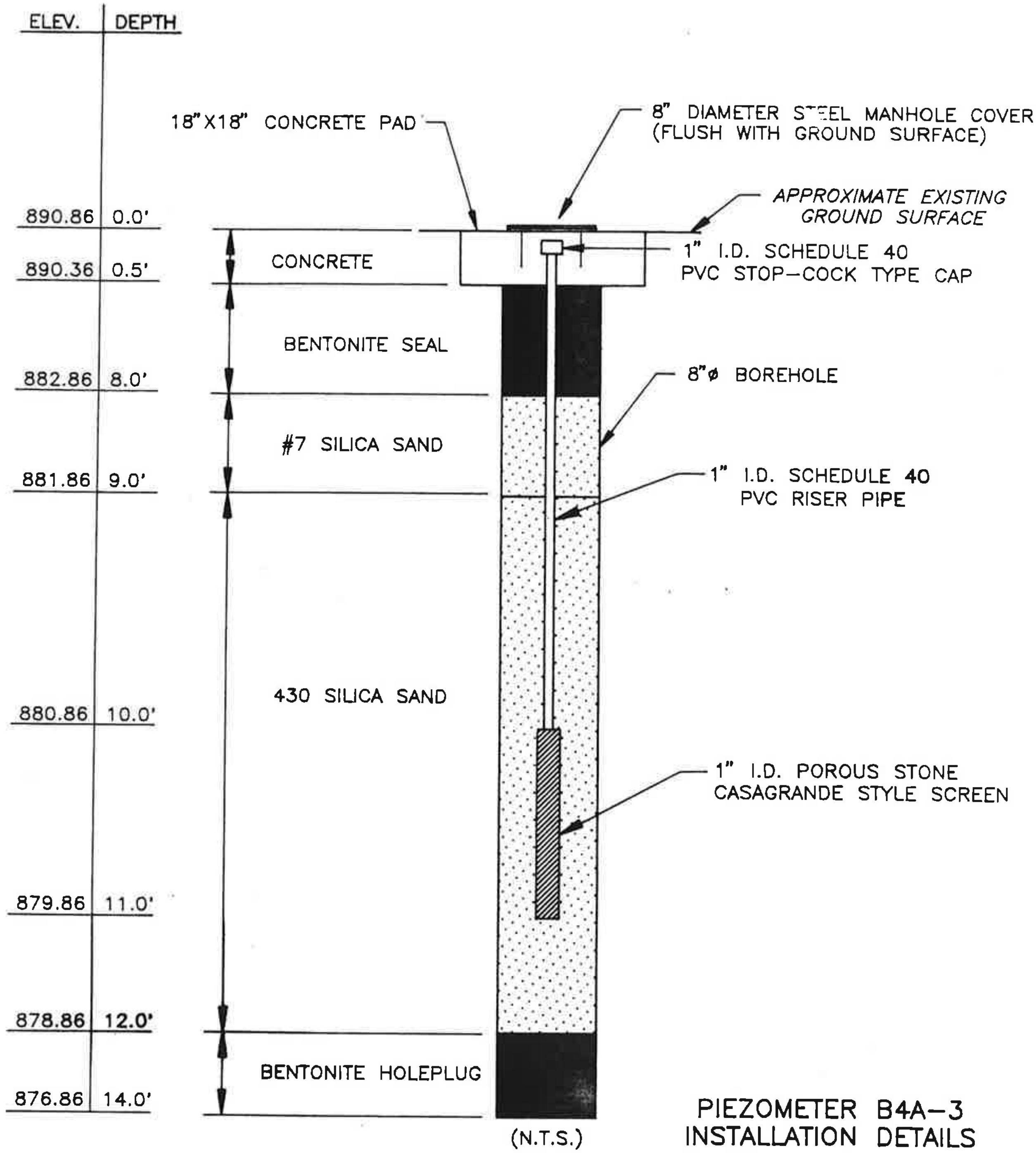
PLOT 1=1



CAD FILE NUMBER 95-1590-E116

CHECKED BY | APPROVED BY

DRAWN BY LPL 10-1-96

PLOT 1=1

PIEZOMETER B4A-3 INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

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COLUMBUS, OHIO

"ELEVATIONS ARE REPORTED IN FEET REFERENCED TO MEAN SEA LEVEL DATUM".

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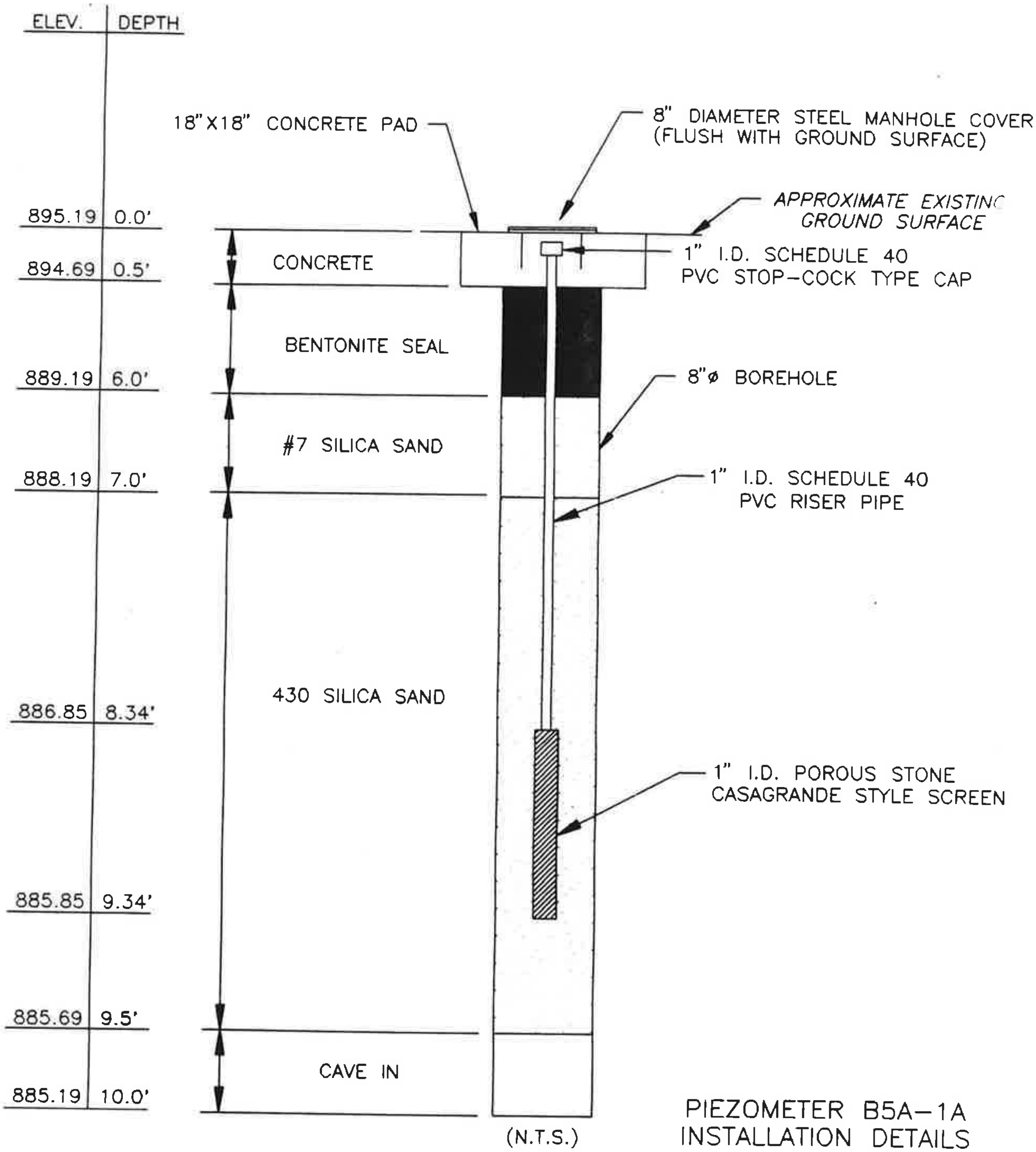

PIEZOMETER B5A-1A INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

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CAD FILE NUMBER	CHECKED BY	APPROVED BY	DRAWN BY	PLOT
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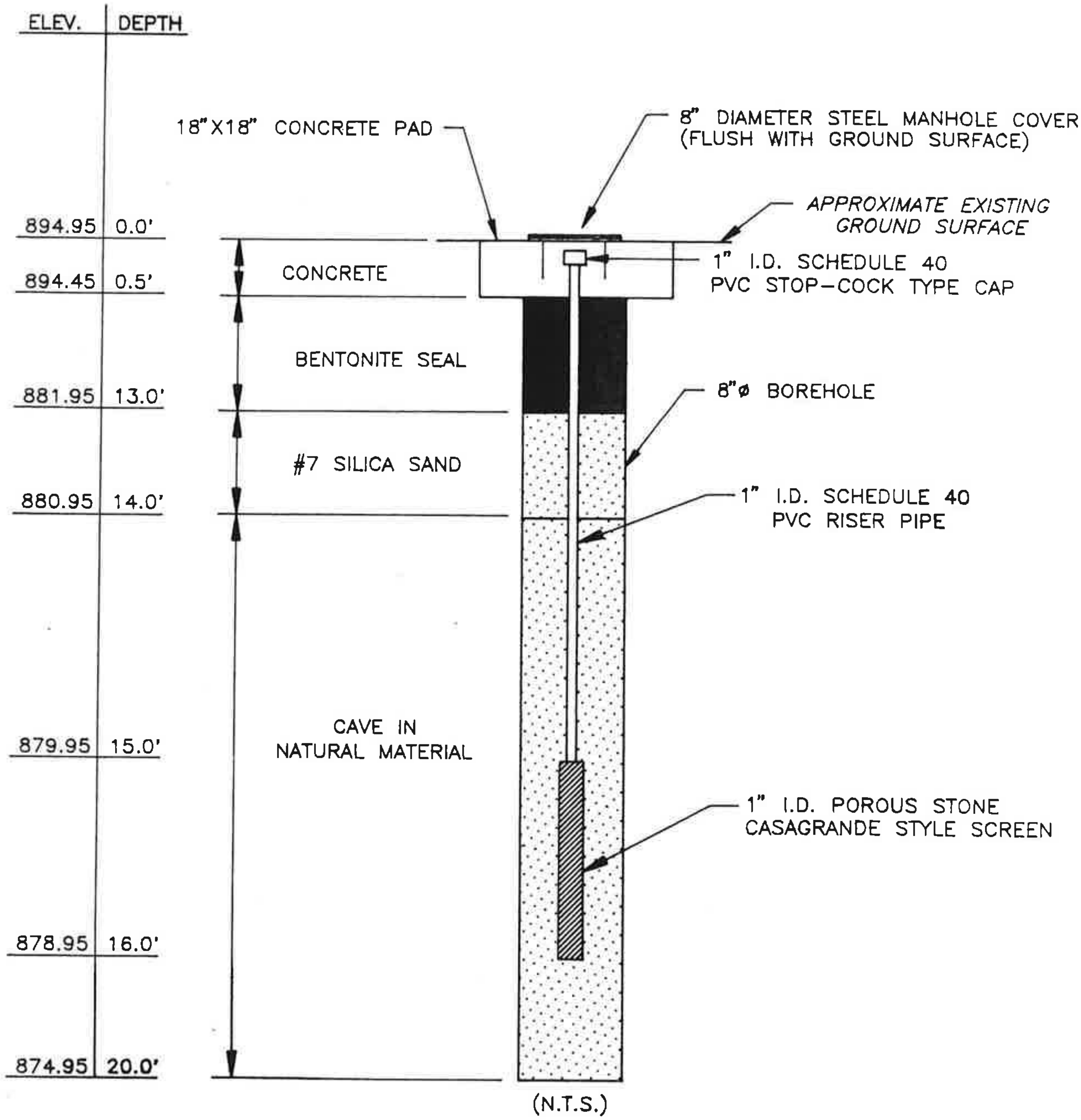


PIEZOMETER B5A-1B
INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

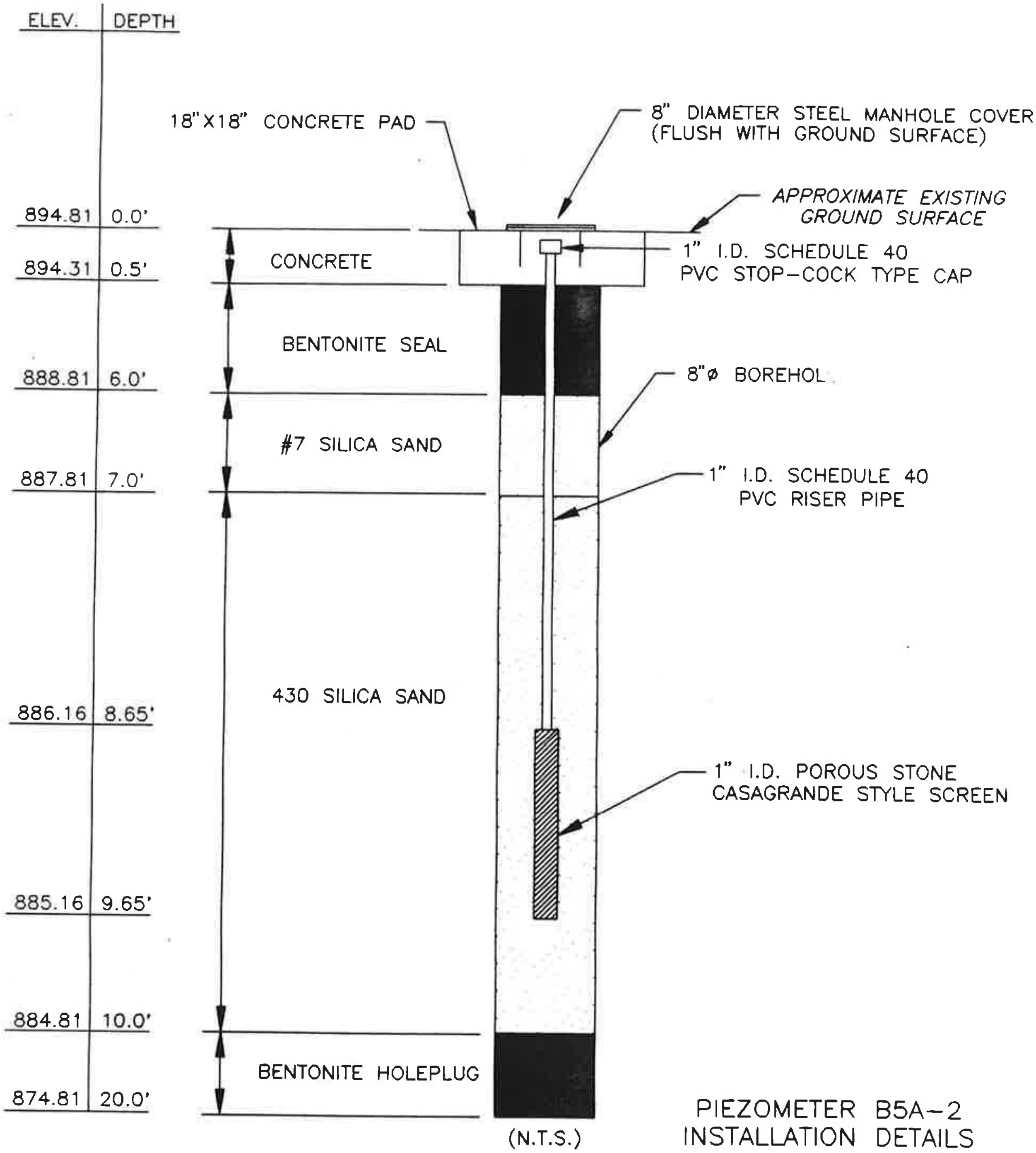
PREPARED FOR

OHIO DEPARTMENT OF NATURAL RESOURCES
COLUMBUS, OHIO

"ELEVATIONS ARE REPORTED IN FEET REFERENCED TO MEAN SEA LEVEL DATUM".
"DO NOT SCALE THIS DRAWING".

Paul C Rizzo Associates, Inc.
CONSULTANTS

CAD FILE NUMBER 95-1590-E118
CHECKED BY
APPROVED BY
LPL
10-1-96
DRAWN BY
PLOT 1=1



PIEZOMETER B5A-2
INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

PREPARED FOR

OHIO DEPARTMENT OF
NATURAL RESOURCES
COLUMBUS, OHIO

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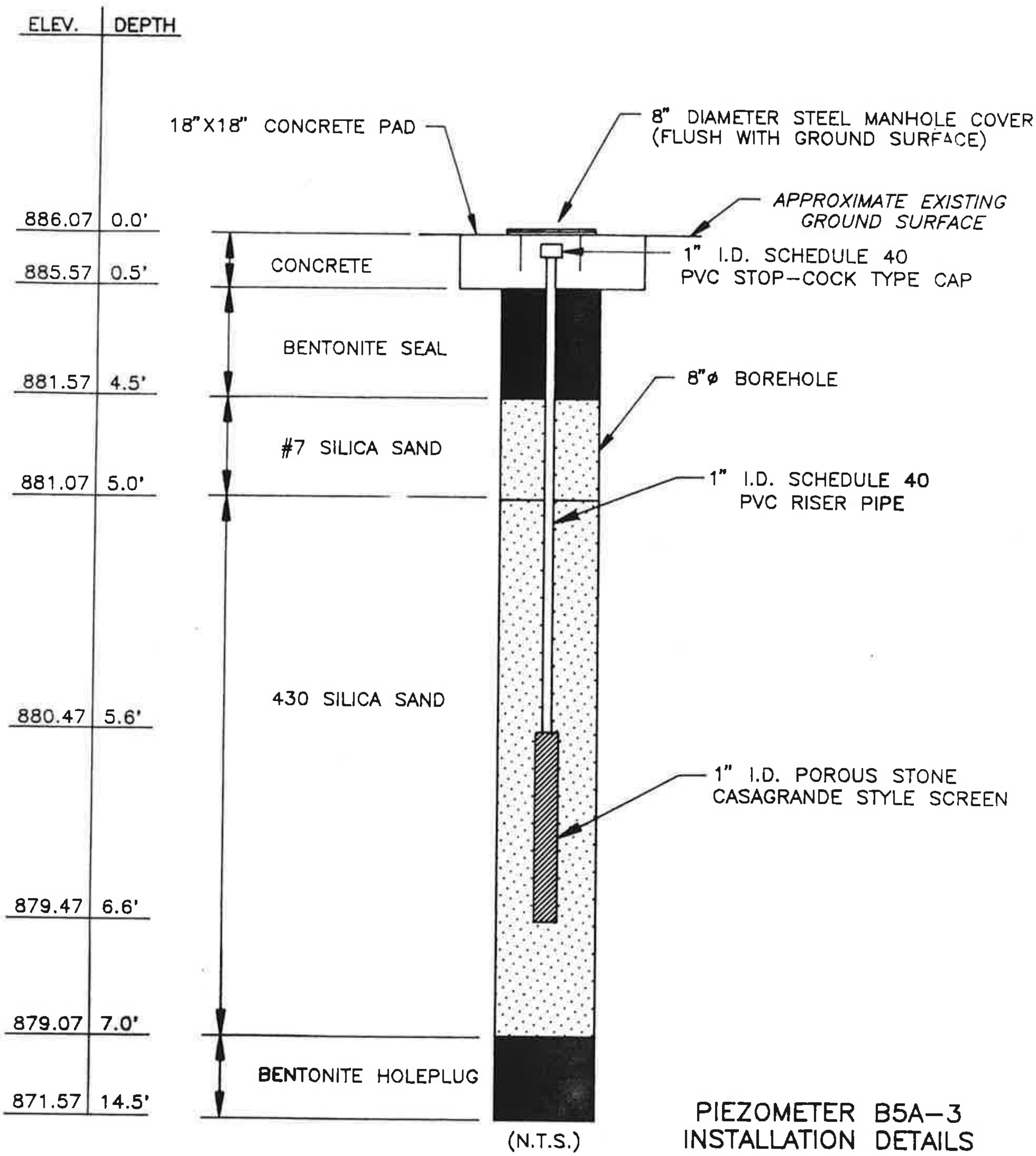
CAD FILE NUMBER 95-1590-A3
CHECKED BY
APPROVED BY
DRAWN BY LPL 10-1-96
PLOT 1=1



PIEZOMETER B5A-3 INSTALLATION DETAILS

BUCKEYE LAKE STATE PARK
BUCKEYE LAKE DAM STABILITY STUDY
DNR736 730-96-034

PREPARED FOR

OHIO DEPARTMENT OF NATURAL RESOURCES
COLUMBUS, OHIO

"ELEVATIONS ARE REPORTED IN FEET REFERENCED TO MEAN SEA LEVEL DATUM".
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CAD FILE NUMBER 95-1590-E120
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PLOT 1=1

APPENDIX B

GEOTECHNICAL LABORATORY RESULTS

- **PHYSICAL PROPERTIES**
- **HYDRAULIC CONDUCTIVITY (PERMEABILITY)**
- **TRIAXIAL SHEAR TESTS**

PHYSICAL PROPERTIES

CTL Engineering Inc.
2860 Fisher Road, P.O. Box 44548, Columbus, Ohio 43204
Phone: 614/276-8123 • Fax: 614/276-6377
E-mail: ctl@ctleng.com

Consulting Engineers • Testing • Inspection Services • Analytical Laboratories

Established 1927

August 21, 1996

Paul C. Rizzo Associates, Inc.
Lionmark Corporate Center
4605 Hilton Corporate Drive
Columbus, Ohio 43232

Attention: Mr. Roy Stanley

Reference: Soils Laboratory Testing
Buckeye Lake Dam
Fairfield-Licking Counties, Ohio
CTL Project No. 96050030

Dear Mr. Stanley:

In accordance with your authorization, CTL Engineering, Inc. has completed the laboratory testing on the soil samples from the above referenced project. Results of the testing are enclosed and are summarized in the attached table.

Thank you for the opportunity to be of service to you on this project. If you have any questions please do not hesitate to contact our office.

Respectfully Submitted,

CTL ENGINEERING, INC.

Joe Grani, P.E.
Project Engineer

Enclosure

SUMMARY OF LABORATORY TESTING

Sample No.	Grain Size Distribution						Atterberg Limits			Natural Moisture Content (%)	Unified Soil Classificaiton System		Hydraulic Conductivity (cm/sec)
	GR	CS	MS	FS	SI	CL	LL	PL	PI		Group Symbol	Group Name	
B2A-3, #2	---	---	---	---	---	---	---	---	---	26.0	---	---	---
B2A-3, #3	0	0	1	7	70	22	30	21	9	32.7	CL	Lean Clay	---
B2A-3, #4	---	---	---	---	---	---	---	---	---	27.8	---	---	---
B2A-3, #5	0	0	0	1	75	24	28	22	6	25.1	CL-ML	Silty Clay	---
B1A-1B, #4	0	0	3	14	50	33	34	18	16	30.8	CL	Lean Clay with Sand	---
B1A-1B, #6	---	---	---	---	---	---	---	---	---	22.4	---	---	---
B1A-1B, #7	5	4	12	18	38	23	25	16	9	13.7	CL	Sandy Lean Clay	---
B1A-1B, #9	---	---	---	---	---	---	---	---	---	12.3	---	---	---

Notes:
GR = Percent Gravel
CS = Percent Coarse Sand
MS = Percent Medium Sand
FS = Percent Fine Sand
SI = Percent Silt
CL = Percent Clay
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
NP = Non-Plastic

SUMMARY OF LABORATORY TESTING (cont.)

Sample No.	Grain Size Distribution						Atterberg Limits			Natural Moisture Content (%)	Unified Soil Classificaiton System		Hydraulic Conductivity (cm/sec)
	GR	CS	MS	FS	SI	CL	LL	PL	PI		Group Symbol	Group Name	
B1A-2, #3	---	---	---	---	---	---	---	---	---	25.6	---	---	---
B1A-2, #5	4	1	5	24	41	25	31	18	13	19.7	CL	Sandy Lean Clay	---
B1A-2, #7	---	---	---	---	---	---	---	---	---	28.3	---	---	---
B1A-2, #8	1	2	7	23	44	23	24	17	7	15.6	CL-ML	Sandy Silty Clay	---
B1A-3, ST-2	0	0	2	19	36	43	47	19	28	27.3	CL	Lean Clay with Sand	3.7×10^{-6}
B1A-3, #3	25	15	22	10	15	13	NP	NP	NP	16.9	SM	Silty Sand with Gravel	---
B2A-1B, #2	---	---	---	---	---	---	---	---	---	13.3	---	---	---
B2A-1B, #3	---	---	---	---	---	---	---	---	---	23.9	---	---	---
B2A-1B, #4	1	2	13	39	19	26	35	17	18	20.7	SC	Clayey Sand	---
B2A-1B, #8	0	0	0	1	62	37	32	19	13	28.3	CL	Lean Clay	---

Notes:
GR = Percent Gravel
CS = Percent Coarse Sand
MS = Percent Medium Sand
FS = Percent Fine Sand
SI = Percent Silt
CL = Percent Clay
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
NP = Non-Plastic

CTL ENGINEERING

SUMMARY OF LABORATORY TESTING (cont.)

Sample No.	Grain Size Distribution						Atterberg Limits			Natural Moisture Content (%)	Unified Soil Classificaiton System		Hydraulic Conductivity (cm/sec)
	GR	CS	MS	FS	SI	CL	LL	PL	PI		Group Symbol	Group Name	
B5-1B, #4	---	---	---	---	---	---	---	---	---	19.0	---	---	---
B5-1B, #5	2	2	5	12	45	34	38	17	21	27.7	CL	Lean Clay with Sand	---
B5-1B, #6	---	---	---	---	---	---	---	---	---	35.5	---	---	---
B5-1B, #7	8	1	5	11	36	39	48	17	31	35.3	CL	Lean Clay with Sand	---
B5-1B, #8	---	---	---	---	---	---	---	---	---	27.0	---	---	---
B5-1B, #9	8	4	10	18	28	32	27	15	12	15.6	CL	Sandy Lean Clay	---
B5-2, #4*	---	---	---	---	---	---	---	---	---	---	---	---	---
B5-2, #5	6	4	7	17	39	27	32	17	15	18.5	CL	Sandy Lean Clay	---
B5-2, #8	3	3	5	17	41	31	36	17	19	25.2	CL	Lean Clay with Sand	---
B5-2, #9	1	2	3	4	48	42	33	22	11	25.7	CL	Lean Clay	---

Notes:
GR = Percent Gravel
CS = Percent Coarse Sand
MS = Percent Medium Sand
FS = Percent Fine Sand
SI = Percent Silt
CL = Percent Clay
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
NP = Non-Plastic
* = No Sample

CTL ENGINEERING

SUMMARY OF LABORATORY TESTING (cont.)

Sample No.	Grain Size Distribution						Atterberg Limits			Natural Moisture Content (%)	Unified Soil Classificaiton System		Hydraulic Conductivity (cm/sec)
	GR	CS	MS	FS	SI	CL	LL	PL	PI		Group Symbol	Group Name	
B5-3, ST-3	0	0	0	1	46	53	40	24	16	28.5	CL	Lean Clay	3.7×10^{-7}
B3A-1A, #1	0	0	2	16	46	36	38	21	17	37.0	CL	Lean Clay with Sand	---
B3A-1A, #3	---	---	---	---	---	---	---	---	---	28.9	---	---	---
B3A-1A, #4	0	0	1	11	43	45	38	18	20	27.8	CL	Lean Clay	---
B3A-1A, #5	---	---	---	---	---	---	---	---	---	33.1	---	---	---
B3A-2B, #3	---	---	---	---	---	---	---	---	---	21.9	---	---	---
B3A-2B, #5	0	1	2	10	45	42	42	19	23	22.7	CL	Lean Clay	---
B3A-2B, #6	---	---	---	---	---	---	---	---	---	24.6	---	---	---
B3A-2B, #7	---	---	---	---	---	---	---	---	---	29.1	---	---	---
B3A-2B, #9	1	2	4	16	40	37	34	16	18	26.5	CL	Lean Clay with Sand	---

Notes:

GR = Percent Gravel
CS = Percent Coarse Sand
MS = Percent Medium Sand

FS = Percent Fine Sand
SI = Percent Silt
CL = Percent Clay

LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

NP = Non-Plastic

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SUMMARY OF LABORATORY TESTING (cont.)

Sample No.	Grain Size Distribution						Atterberg Limits			Natural Moisture Content (%)	Unified Soil Classificaiton System		Hydraulic Conductivity (cm/sec)
	GR	CS	MS	FS	SI	CL	LL	PL	PI		Group Symbol	Group Name	
B3A-3, #4	0	1	5	18	41	35	37	19	18	24.4	CL	Lean Clay with Sand	---
B3A-3, #6	0	1	4	20	35	40	45	19	26	25.4	CL	Lean Clay with Sand	---
B4-1B, #3	---	---	---	---	---	---	---	---	---	22.1	---	---	---
B4-1B, #5	0	0	0	8	54	38	35	19	16	29.8	CL	Lean Clay	---
B4-1B, #6	---	---	---	---	---	---	---	---	---	36.1	---	---	---
B4-1B, #8	---	---	---	---	---	---	---	---	---	27.9	---	---	---
B4-1B, #9	0	0	2	19	41	38	35	18	17	---	CL	Lean Clay with Sand	---
B4-2, #2	0	1	2	7	44	46	43	21	22	23.0	CL	Lean Clay	---
B4-2, #3	---	---	---	---	---	---	---	---	---	22.6	---	---	---
B4-2, #6	---	---	---	---	---	---	---	---	---	18.9	---	---	---
B4-2,(8'-10')	---	---	---	---	---	---	---	---	---	---	---	---	7.7×10^{-8}

Notes:

GR = Percent Gravel
CS = Percent Coarse Sand
MS = Percent Medium Sand
FS = Percent Fine Sand
SI = Percent Silt
CL = Percent Clay
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
NP = Non-Plastic

CTL ENGINEERING INC

SUMMARY OF LABORATORY TESTING (cont.)

Sample No.	Grain Size Distribution						Atterberg Limits			Natural Moisture Content (%)	Unified Soil Classificaiton System		Hydraulic Conductivity (cm/sec)
	GR	CS	MS	FS	SI	CL	LL	PL	PI		Group Symbol	Group Name	
B4-3, #2	---	---	---	---	---	---	---	---	---	27.7	---	---	---
B4-3, #4	0	0	1	7	47	45	42	22	20	26.3	CL	Lean Clay	---
B4-3, #5	---	---	---	---	---	---	---	---	---	25.2	---	---	---
B4-3, #6	---	---	---	---	---	---	---	---	---	28.2	---	---	---
B4-3, #7	0	0	1	24	39	36	36	18	18	---	CL	Lean Clay with Sand	---
B2A-2, #2	---	---	---	---	---	---	---	---	---	28.3	---	---	---
B2A-2, #4	5	6	19	25	22	23	30	17	13	21.5	SC	Clayey Sand	---
B2A-2, #5	0	0	0	7	59	34	32	18	14	22.5	CL	Lean Clay	---
B2A-2,(4'-6')	---	---	---	---	---	---	---	---	---	---	---	---	6.5×10^{-7}

Notes:
GR = Percent Gravel
CS = Percent Coarse Sand
MS = Percent Medium Sand
FS = Percent Fine Sand
SI = Percent Silt
CL = Percent Clay
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
NP = Non-Plastic

CTL ENGINEERING

HYDRAULIC CONDUCTIVITY (PERMEABILITY)

Hydraulic Conductivity
ASTM D 5084-Method C

Client:	Paul C. Rizzo Associates, Inc.	Sample	B1A-3	Date:	07/31/96
Project	Buckeye Lake Dam Stability Study		ST-2	Tech:	P.W.
	Buckeye Lake State Park				
Project #	96050030				

Confining Pressure, Cp =	60	psi	or	4220	cm water
Head Pressure (air), Hp =	58	psi	or	4080	cm water
Back Pressure (air), Bp =	56	psi	or	3939	cm water
Pipet Area, a =	0.869	cm^2	(0.869 or 3.65(annulus))		
Pipet Length, Lp =	28.78	cm			
Pipet Volume, Vp =	25	cm^3	Vo = Pipet reading out		
Sample Length, L =	8.349	cm	Vi = Pipet reading in		
Sample Area, A =	41.852	cm^2	t = Time in seconds		
Temperature, T =	21	deg.C			

$$K = (aL/2At) * \ln \frac{(Hp - Bp + ((Vo - Vi) * Lp / Vp)) \quad (t = 1)}{(Hp - Bp + ((Vo - Vi) * Lp / Vp)) \quad (t = 2)}$$

Permeation									
Date	Time	t	Vi	dVi	Vo	dVo	dVo/dVi	K	Notes
07/31/96	09:05		0.0		24.0				Pipet
	09:10		1.1		21.3				
	09:15		2.2		20.1				
	09:20	900	3.1	3.1	19.1	4.9	1.58	5.4E-06	
	09:25	900	4.0	2.9	18.2	3.1	1.07	4.1E-06	
	09:30	900	4.9	2.7	17.4	2.7	1.00	3.8E-06	
	09:35	900	5.7	2.6	16.6	2.5	0.96	3.6E-06	
	09:40	900	6.5	2.5	15.8	2.4	0.96	3.5E-06	

Notes: Average final 4 readings = 3.8E-06 cm/sec
Corrected permeability = 3.7E-06 cm/sec

Test Specimen Information: Moisture Content = 30.3% Dry Unit Weight= 90.7 pcf
L= 3.287" D= 2.874" Wt= 1.437 lb Wet Unit Wt= 116.5 pcf

CTL ENGINEERING INC

Hydraulic Conductivity
ASTM D 5084-Method C

Client:	Paul C. Rizzo Associates, Inc.	Sample	B2A-2	Date:	09/19/96
Project	Buckeye Lake Dam Stability Study		4'-6'	Tech:	P.W.
	Buckeye Lake State Park				
Project #	96050030				

Confining Pressure, Cp =	60	psi	or	4220	cm water
Head Pressure (air), Hp =	59	psi	or	4150	cm water
Back Pressure (air), Bp =	58	psi	or	4080	cm water
Pipet Area, a =	0.869	cm ^ 2	(0.869 or 3.65(annulus))		
Pipet Length, Lp =	28.78	cm			
Pipet Volume, Vp =	25	cm ^ 3	Vo = Pipet reading out		
Sample Length, L =	8.628	cm	Vi = Pipet reading in		
Sample Area, A =	41.592	cm ^ 2	t = Time in seconds		
Temperature, T =	22	deg.C			

$$K = (aL/2At) * \ln \frac{(Hp - Bp + ((Vo - Vi) * Lp / Vp)) \quad (t = 1)}{(Hp - Bp + ((Vo - Vi) * Lp / Vp)) \quad (t = 2)}$$

Permeation									
Date	Time	t	Vi	dVi	Vo	dVo	dVo/dVi	K	Notes
9/19/96	14:15		0.0		24.0				Pipet
	14:45		0.4		22.9				
	15:15		0.9		22.1				
	15:45		1.4		21.5				
	16:15		1.9		20.9				
	16:45	9000	2.4	2.4	20.3	3.7	1.54	7.4E-07	
	17:15	9000	2.9	2.5	19.8	3.1	1.24	6.9E-07	
	17:45	9000	3.4	2.5	19.3	2.8	1.12	6.7E-07	
	18:15	9000	3.9	2.5	18.7	2.8	1.12	6.8E-07	
	18:45	9000	4.4	2.5	18.2	2.7	1.08	6.7E-07	

Notes: Average final 4 readings = 6.8E-07 cm/sec
Corrected permeability = 6.5E-07 cm/sec

Test Specimen Information: Moisture Content = 26.1% Dry Unit Weight= 91.6 pcf
L= 3.397" D= 2.865" Wt= 1.463 lb Wet Unit Wt= 117.1 pcf

CTL ENGINEERING INC

Hydraulic Conductivity

ASTM D 5084-Method C

Client:	Paul C. Rizzo Associates, Inc.	Sample	B4-2	Date:	09/19/96
Project	Buckeye Lake Dam Stability Study		8'-10'	Tech:	P.W.
	Buckeye Lake State Park				
Project #	96050030				

Confining Pressure, Cp =	60	psi	or	4220	cm water
Head Pressure (air), Hp =	58	psi	or	4080	cm water
Back Pressure (air), Bp =	56	psi	or	3939	cm water
Pipet Area, a =	0.869	cm^2		(0.869 or 3.65(annulus))	
Pipet Length, Lp =	28.78	cm			
Pipet Volume, Vp =	25	cm^3		Vo = Pipet reading out	
Sample Length, L =	8.164	cm		Vi = Pipet reading in	
Sample Area, A =	41.215	cm^2		t = Time in seconds	
Temperature, T =	22	deg.C			

$$K = (aL/2At) * \ln \frac{(Hp - Bp + ((Vo - Vi) * Lp / Vp)) \quad (t = 1)}{(Hp - Bp + ((Vo - Vi) * Lp / Vp)) \quad (t = 2)}$$

Permeation									
Date	Time	t	Vi	dVi	Vo	dVo	dVo/dVi	K	Notes
9/19/96	14:15		0.0		24.0				Pipet
	15:15		0.1		22.8				
	16:15		0.3		22.2				
	17:15		0.5		21.9				
	18:15		0.7		21.6				
9/20/96	08:15	64800	3.9	3.9	18.1	5.9	1.51	9.2E-08	
	09:15	64800	4.1	4.0	17.9	4.9	1.23	8.4E-08	
	10:15	64800	4.3	4.0	17.7	4.5	1.13	8.1E-08	
	11:15	64800	4.5	4.0	17.5	4.4	1.10	8.0E-08	
	12:15	64800	4.7	4.0	17.3	4.3	1.08	7.9E-08	

Notes: Average final 4 readings = 8.1E-08 cm/sec

Corrected permeability = 7.7E-08 cm/sec

Test Specimen Information: Moisture Content = 24.8% Dry Unit Weight= 97.2 pcf

L= 3.214" D= 2.852" Wt= 1.440 lb Wet Unit Wt= 122.1 pcf

CTL ENGINEERING INC

Hydraulic Conductivity
ASTM D 5084-Method C

Client:	Paul C. Rizzo Associates, Inc.	Sample	B5-3	Date:	07/31/96
Project	Buckeye Lake Dam Stability Study		ST-3	Tech:	P.W.
	Buckeye Lake State Park				
Project #	96050030				

Confining Pressure, Cp =	60	psi	or	4220	cm water	
Head Pressure (air), Hp =	58	psi	or	4080	cm water	
Back Pressure (air), Bp =	56	psi	or	3939	cm water	
Pipet Area, a =	0.869	cm^2		(0.869 or 3.65(annulus))		
Pipet Length, Lp =	28.78	cm				
Pipet Volume, Vp =	25	cm^3		Vo = Pipet reading out		
Sample Length, L =	8.506	cm		Vi = Pipet reading in		
Sample Area, A =	41.013	cm^2		t = Time in seconds		
Temperature, T =	21	deg.C				

$$K = (aL/2At) * \ln \frac{(Hp - Bp + ((Vo - Vi) * Lp / Vp))\quad (t = 1)}{(Hp - Bp + ((Vo - Vi) * Lp / Vp))\quad (t = 2)}$$

Permeation									
Date	Time	t	Vi	dVi	Vo	dVo	dVo/dVi	K	Notes
07/31/96	09:05		0.0		24.0				Pipet
	09:35		0.4		22.8				
	10:05		0.9		22.2				
	10:35		1.4		21.7				
	11:05		1.9		21.2				
	13:35	16200	4.5	4.5	18.5	5.5	1.22	3.9E-07	
	14:05	16200	5.0	4.6	17.9	4.9	1.07	3.8E-07	
	14:35	16200	5.5	4.6	17.4	4.8	1.04	3.8E-07	
	15:05	16200	6.0	4.6	17.0	4.7	1.02	3.8E-07	
	15:35	16200	6.5	4.6	16.6	4.6	1.00	3.7E-07	

Notes: Average final 4 readings = 3.8E-07 cm/sec
Corrected permeability = 3.7E-07 cm/sec

Test Specimen Information: Moisture Content = 28.0% Dry Unit Weight= 94.9 pcf
L= 3.349" D= 2.845" Wt= 1.501 lb Wet Unit Wt= 121.9 pcf

CTL ENGINEERING

TRIAXIAL SHEAR TESTS

CTL Engineering Inc.
2860 Fisher Road, P.O. Box 44548, Columbus, Ohio 43204
Phone: 614/276-8123 · Fax: 614/276-6377
E-mail: ctl@ctleng.com

October 11, 1996

Paul C. Rizzo Associates, Inc.
Lionmark Corporate Center
4605 Hilton Corporate Drive
Columbus, Ohio 43232

Attention: Mr. Roy Stanley

Reference: Soils Laboratory Testing
Buckeye Lake Dam Stability Analysis
Buckeye Lake State Park
CTL Project No. 96050030

Dear Mr. Stanley:

Enclosed you will find the requested curves which were generated from the triaxial test data. All testing was performed in accordance with ASTM D 4767 procedures.

Pursuant to your request, the confining pressure for the samples in the triaxial tests were 0.8, 1.0 and 2.0 times the total overburden pressure. The total overburden pressure was computed using the measured total unit weight of the samples. Additionally, each sample was loaded to in excess of 20 percent axial strain.

A summary of the soil friction angle and cohesion values is provided below. It should be noted that a range of friction angle and cohesion values was provided for the effective stress case for samples B2A-2 and B4-2.

Sample No.	Depth (feet)	Mohr Circle				q vs. p			
		Effective Stress		Total Stress		Effective Stress		Total Stress	
		Friction Angle (deg)	Cohesion (psf)	Friction Angle (deg)	Cohesion (psf)	Friction Angle (deg)	Cohesion (psf)	Friction Angle (deg)	Cohesion (psf)
B2A-2	4' - 6'	18.5	738	19.0	465	24.5	511	19.0	479
		39.5	0			39.0	0		
B4-2	8' - 10'	29.5	651	29.0	349	29.9	658	29.2	306
		39.0	0			38.7	0		
B5-3	3.5' - 7'	30.0	279	35.5	628	29.2	533	36.0	518

Because of the relatively low overburden pressure of the samples, the difference in confining pressures between test data points (taken at 0.8, 1.0 and 2.0 times the overburden) was relatively small. This small spacing between data points resulted in closely spaced Mohr Circles and therefore, a range of friction angle and cohesion values were provided.

Thank you for the opportunity to be of service to you on this project. If you have any questions please do not hesitate to contact our office.

Respectfully Submitted,

CTL ENGINEERING, INC.

Joe Grani, P.E.
Project Engineer

Enclosure

CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

Client: Paul C. Rizzo Associates, Inc.		Sample ID:	B2A-2
Project: Buckeye Lake Dam Stability Study		Depth Interval:	4'-6'
Project #: 96050030		Compaction (%):	---
Date: 9/27/96		Cell Confining Pressure (psf):	504
Checked: Joe Grani			
INITIAL CONDITIONS		FINAL CONDITIONS	
Dry Unit Weight (pcf):	103.9	Dry Unit Weight (pcf):	103.9
Moisture Content (%):	19.2	Moisture Content (%):	21.8
Total Unit Weight (pcf):	123.8	Total Unit Weight (pcf):	126.6
B Parameter:	0.98	Area (Ac, Method A) (sq.in.):	6.341

	Effective Stresses			Total Stresses		
Axial Strain (%)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Pore Press. (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Deviator Stress (psf)
0.0	504	504	8136	504	504	0
0.1	1052	374	8266	1182	504	678
0.2	1084	317	8323	1271	504	767
0.3	1099	288	8352	1315	504	811
0.4	1129	274	8366	1359	504	855
0.5	1158	259	8381	1403	504	899
0.9	1318	245	8395	1577	504	1073
1.3	1424	245	8395	1683	504	1179
1.8	1520	259	8381	1765	504	1261
2.2	1596	274	8366	1826	504	1322
2.7	1669	288	8352	1885	504	1381
3.1	1735	317	8323	1922	504	1418
3.6	1786	331	8309	1959	504	1455
4.5	1866	360	8280	2010	504	1506
5.4	1929	374	8266	2059	504	1555
6.3	1957	374	8266	2087	504	1583
7.2	1998	389	8251	2113	504	1609
8.0	2038	403	8237	2139	504	1635
8.9	2078	418	8222	2164	504	1660
9.8	2116	432	8208	2188	504	1684
10.7	2154	446	8194	2212	504	1708
11.6	2191	461	8179	2234	504	1730
12.5	2227	475	8165	2256	504	1752
13.4	2243	490	8150	2257	504	1753
14.3	2264	490	8150	2278	504	1774
15.2	2278	504	8136	2278	504	1774
16.1	2311	518	8122	2297	504	1793
17.0	2329	518	8122	2315	504	1811
17.9	2343	533	8107	2314	504	1810
18.8	2360	533	8107	2331	504	1827
19.7	2372	547	8093	2329	504	1825
20.6	2384	562	8078	2326	504	1822

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Failure Criterion = 18.8 % Axial Strain

At Failure

Effective Stresses		Total Stresses	
Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)
2360	533	2331	504

Principle Stress Difference = 1827 psf

CTL ENGINEERING INC

CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

Client:	Paul C. Rizzo Associates, Inc.	Sample ID:	B2A-2
Project:	Buckeye Lake Dam Stability Study	Depth Interval:	4'-6'
Project #:	96050030	Compaction (%):	---
Date:	9/27/96	Cell Confining Pressure (psf):	619.2
Checked:	Joe Grani		
INITIAL CONDITIONS		FINAL CONDITIONS	
Dry Unit Weight (pcf):	102.4	Dry Unit Weight (pcf):	102.4
Moisture Content (%):	22.6	Moisture Content (%):	21.7
Total Unit Weight (pcf):	125.5	Total Unit Weight (pcf):	124.6
B Parameter:	0.96	Area (Ac, Method A) (sq.in.):	6.332

	Effective Stresses			Total Stresses		
Axial Strain (%)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Pore Press. (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Deviator Stress (psf)
0.0	619	619	8021	619	619	0
0.1	1036	446	8194	1209	619	590
0.2	1069	346	8294	1343	619	724
0.3	1056	288	8352	1387	619	768
0.4	1057	245	8395	1431	619	812
0.4	1072	216	8424	1475	619	856
0.9	1176	101	8539	1694	619	1075
1.3	1320	72	8568	1867	619	1248
1.7	1454	58	8582	2016	619	1397
2.2	1572	72	8568	2119	619	1500
2.6	1682	101	8539	2200	619	1581
3.1	1747	130	8510	2237	619	1618
3.5	1812	158	8482	2273	619	1654
4.4	1962	216	8424	2365	619	1746
5.2	2096	259	8381	2456	619	1837
6.1	2213	288	8352	2544	619	1925
7.0	2293	302	8338	2610	619	1991
7.8	2407	331	8309	2695	619	2076
8.7	2483	346	8294	2757	619	2138
9.6	2573	374	8266	2818	619	2199
10.5	2661	403	8237	2877	619	2258
11.3	2748	432	8208	2935	619	2316
12.2	2867	475	8165	3011	619	2392
13.1	2950	504	8136	3065	619	2446
13.9	3013	533	8107	3099	619	2480
14.8	3092	562	8078	3150	619	2531
15.7	3186	605	8035	3200	619	2581
16.6	3244	634	8006	3230	619	2611
17.4	3301	662	7978	3258	619	2639
18.3	3390	706	7934	3304	619	2685
19.2	3460	749	7891	3330	619	2711
20.0	3512	778	7862	3354	619	2735

CTL ENGINEERING INC

Failure Criterion = 20.0 % Axial Strain

At Failure

Effective Stresses		Total Stresses	
Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)
3511	777	3353	619

Principle Stress Difference = 2734 psf

CTL ENGINEERING INC

CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

Client:	Paul C. Rizzo Associates, Inc.	Sample ID:	B2A-2
Project:	Buckeye Lake Dam Stability Study	Depth Interval:	4'-6'
Project #:	96050030	Compaction (%):	---
Date:	9/27/96	Cell Confining Pressure (psf):	1252.8
Checked:	Joe Grani		
INITIAL CONDITIONS		FINAL CONDITIONS	
Dry Unit Weight (pcf):	98.5	Dry Unit Weight (pcf):	98.5
Moisture Content (%):	27.7	Moisture Content (%):	22.4
Total Unit Weight (pcf):	125.8	Total Unit Weight (pcf):	120.6
B Parameter:	0.96	Area (Ac, Method A) (sq.in.):	6.271

	Effective Stresses			Total Stresses		
Axial Strain (%)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Pore Press. (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Deviator Stress (psf)
0.0	1253	1253	7387	1253	1253	0
0.1	1744	922	7718	2075	1253	822
0.2	1735	778	7862	2210	1253	957
0.3	1746	677	7963	2322	1253	1069
0.4	1741	605	8035	2389	1253	1136
0.4	1750	547	8093	2456	1253	1203
0.9	1854	432	8208	2675	1253	1422
1.3	1961	389	8251	2825	1253	1572
1.8	2029	374	8266	2907	1253	1654
2[illegible]	2051	360	8280	2944	1253	1691
2.7	2110	360	8280	3003	1253	1750
3.1	2183	374	8266	3061	1253	1808
3.6	2218	374	8266	3096	1253	1843
4.4	2288	374	8266	3166	1253	1913
5.3	2356	374	8266	3234	1253	1981
6.2	2436	389	8251	3300	1253	2047
7.1	2509	418	8222	3344	1253	2091
8.0	2566	432	8208	3387	1253	2134
8.9	2628	432	8208	3449	1253	2196
9.8	2724	446	8194	3530	1253	2277
10.7	2736	461	8179	3528	1253	2275
11.5	2773	461	8179	3565	1253	2312
12.4	2824	475	8165	3602	1253	2349
13.3	2874	490	8150	3637	1253	2384
14.2	2908	490	8150	3671	1253	2418
15.1	2935	504	8136	3684	1253	2431
16.0	2963	518	8122	3697	1253	2444
16.9	2994	518	8122	3728	1253	2475
17.8	3037	533	8107	3757	1253	2504
18.7	3061	547	8093	3767	1253	2514
19.5	3089	547	8093	3795	1253	2542
20.4	3130	562	8078	3821	1253	2568

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Failure Criterion = 20.0 % Axial Strain

At Failure

Effective Stresses		Total Stresses	
Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)
3111	555	3809	1253

Principle Stress Difference = 2556 psf

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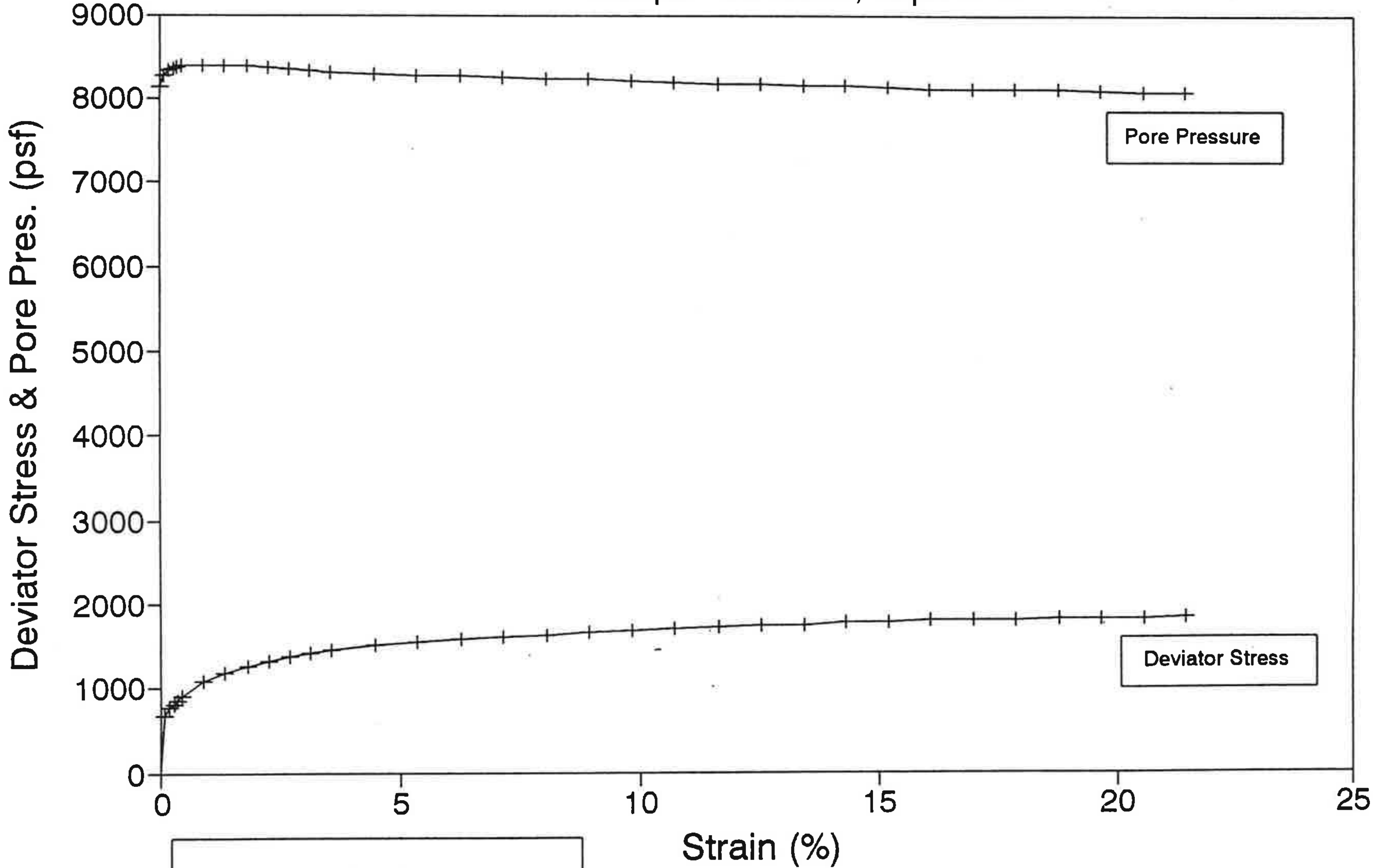
Deviator Stress, Pore Pres. vs Strain

Confining Pressure=504 psf

Sample No. B2A-2, Depth 4'-6'



Paul C. Rizzo Associates, Inc.
Buckeye Lake Dam Stability Study
Buckeye Lake State Park
96050030

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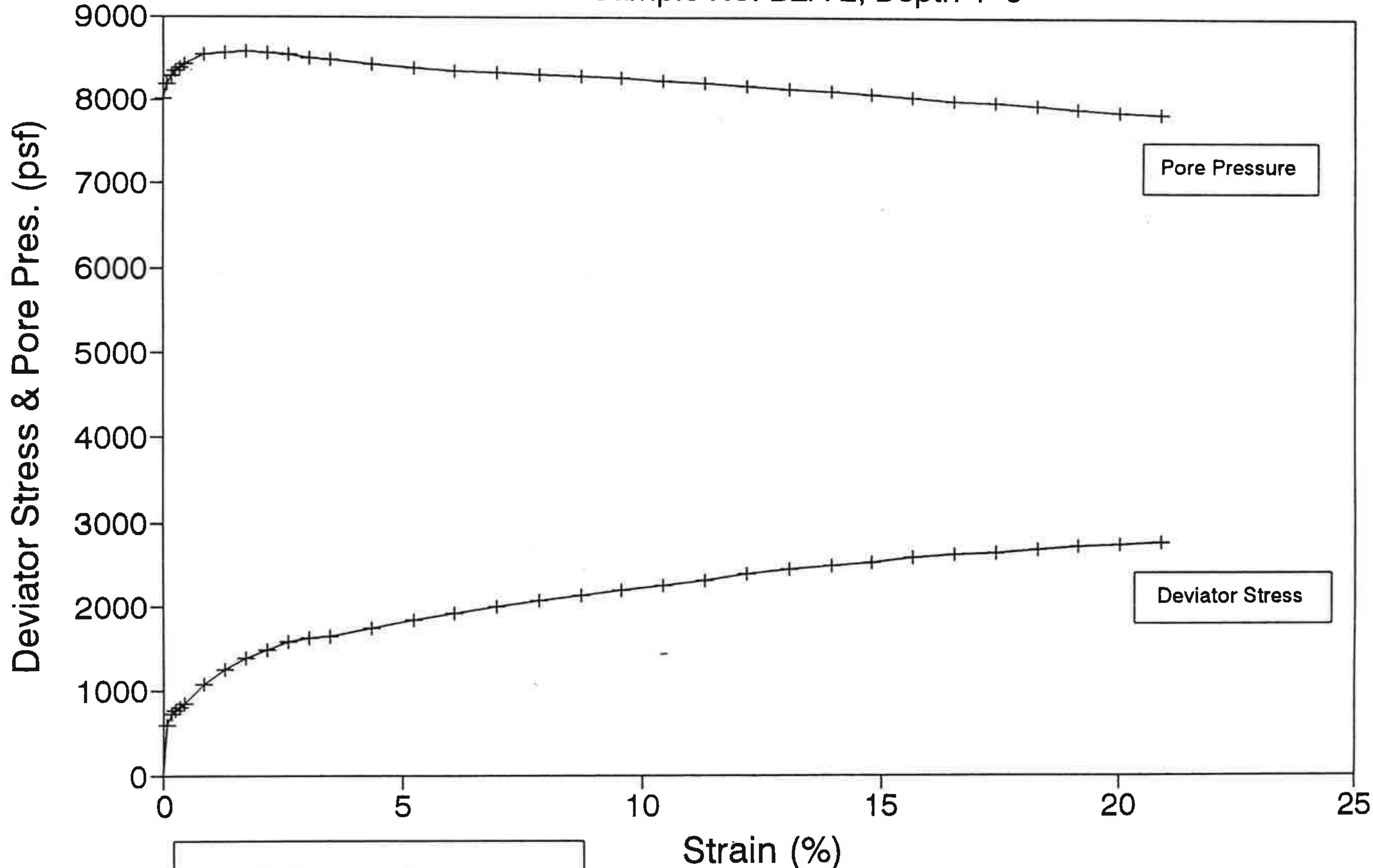
Deviator Stress, Pore Pres. vs Strain

Confining Pressure=619.2 psf

Sample No. B2A-2, Depth 4'-6'



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Buckeye Lake Dam Stability Study
Buckeye Lake State Park
96050030

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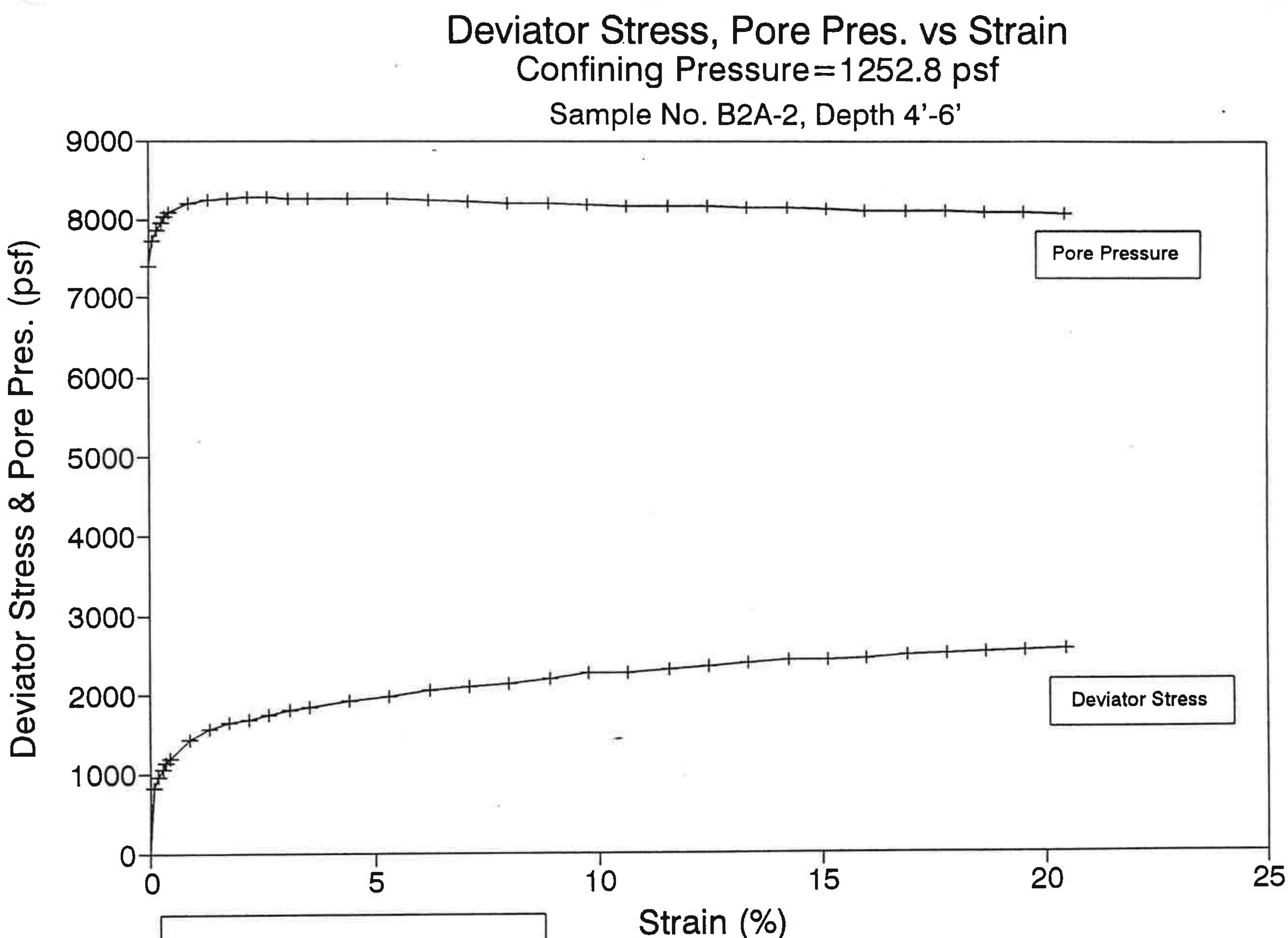

Paul C. Rizzo Associates, Inc.
Buckeye Lake Dam Stability Study
Buckeye Lake State Park
96050030

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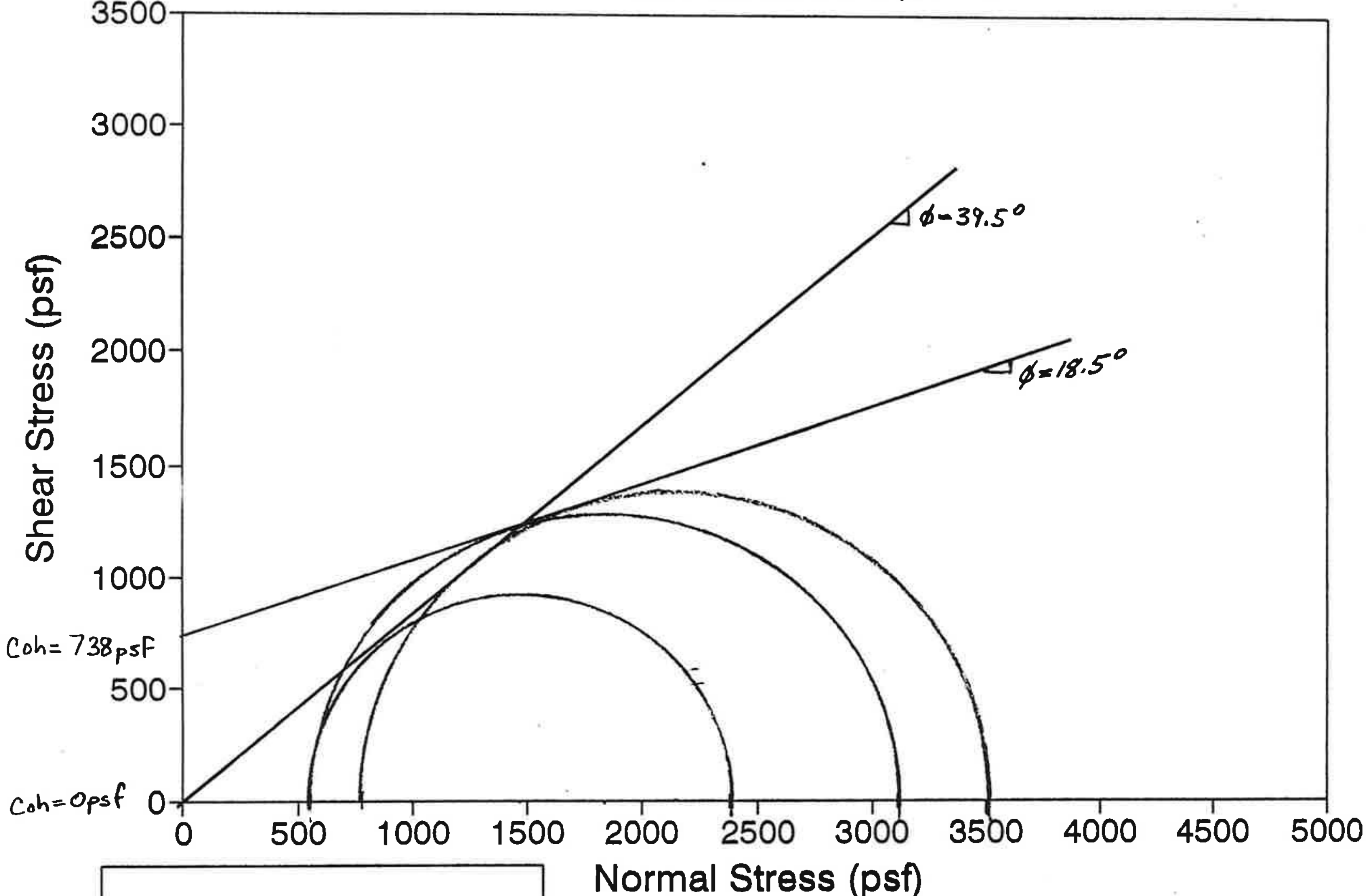
Mohr Circle
Effective Stress

Sample No. B2A-2, Depth 4'-6'



Paul C. Rizzo Associates, Inc.
Buckeye Lake Dam Stability Study
Buckeye Lake State Park
96050030

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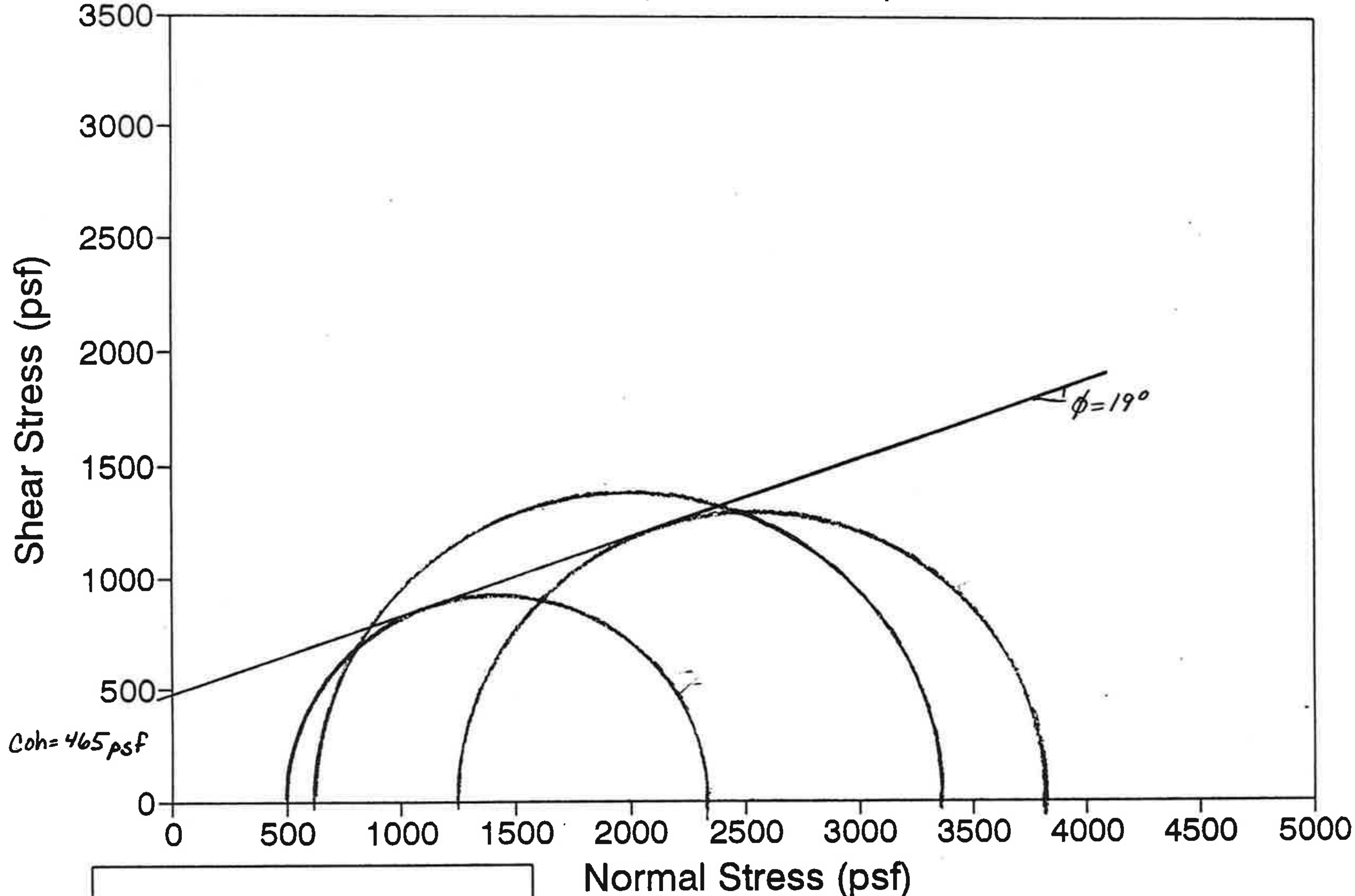
Mohr Circle

Total Stress

Sample No. B2A-2, Depth 4'-6'



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Buckeye Lake Dam Stability Study
Buckeye Lake State Park
96050030

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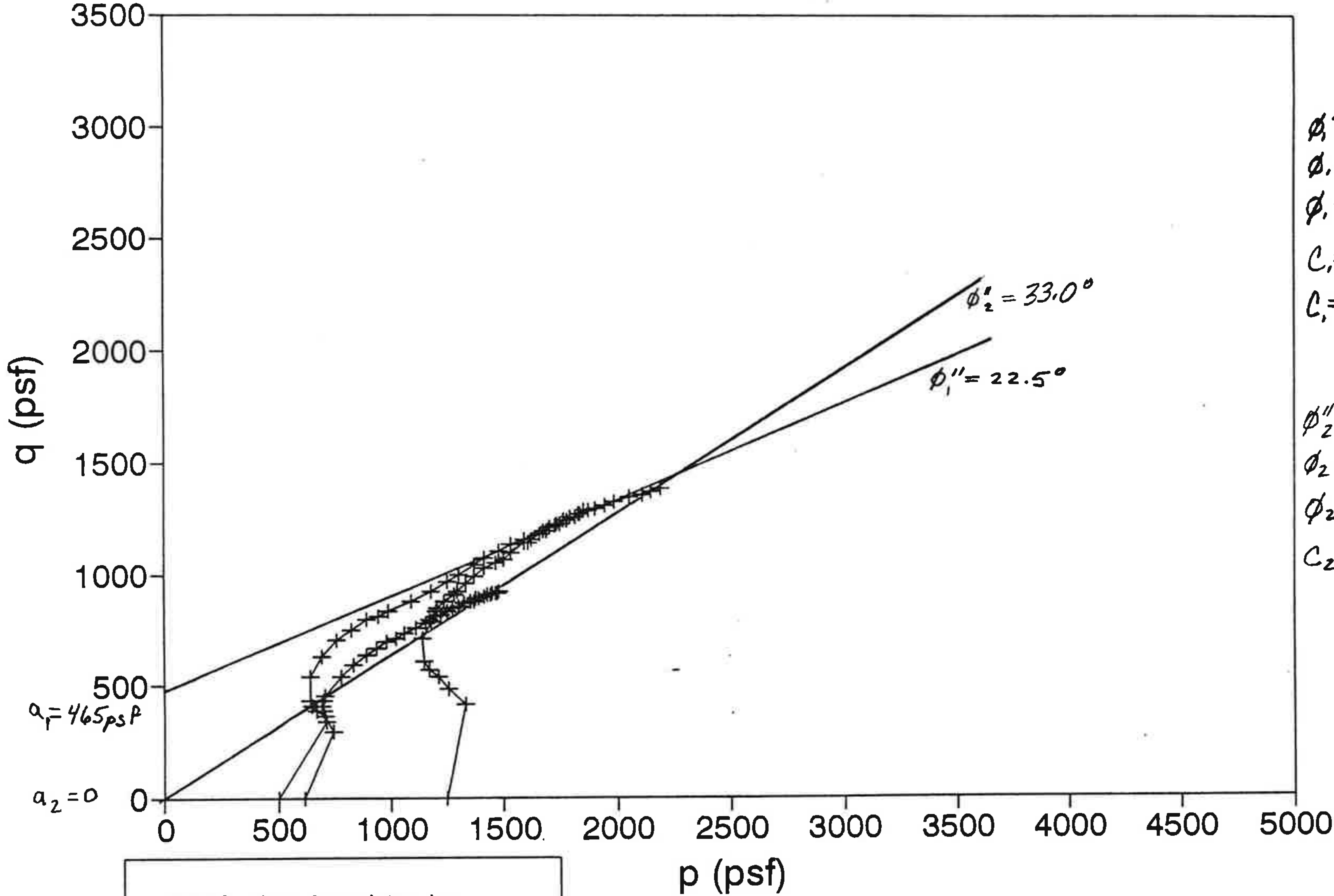
q vs. p
Effective Stress

Sample No. B2A-2, Depth 4'-6'



$\phi_1'' = 22.5°$
$\phi_1 = \sin^{-1}(\tan 22.5)$
$\phi_1 = 24.5°$
$C_1 = a \sec \phi$
$C_1 = 511 psf$

$\phi_2'' = 33.0°$
$\phi_2 = \sin^{-1}(\tan 33.0)$
$\phi_2 = 39.0°$
$C_2 = 0 psf$

Paul C. Rizzo Associates, Inc.
Buckeye Lake Dam Stability Study
Buckeye Lake State Park
96050030

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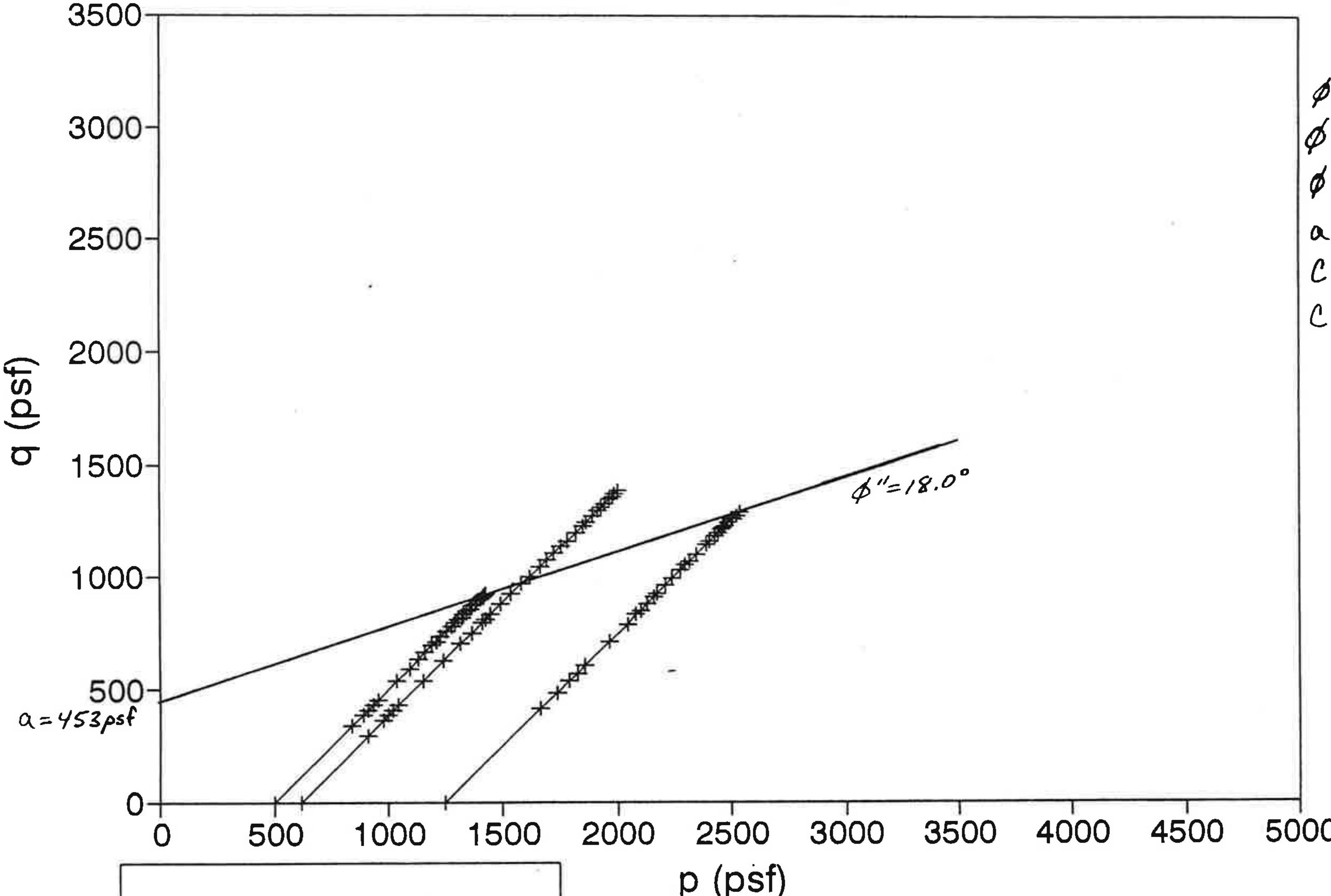
q vs. p
Total Stress

Sample No. B2A-2, Depth 4'-6'



$\phi'' = 18.0°$

$\phi = \sin^{-1}(\tan\phi'')$

$\phi = 19.0°$

$a = 453 psf$

$C = a \sec\phi$

$C = 479 psf$

Paul C. Rizzo Associates, Inc.
Buckeye Lake Dam Stability Study
Buckeye Lake State Park
96050030

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CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

Client:	Paul C. Rizzo Associates, Inc.	Sample ID:	B4-2
Project:	Buckeye Lake	Depth Interval:	8'-10'
Project #:	96050030	Compaction (%):	---
Date:	9/27/96	Cell Confining Pressure (psf):	878.4
Checked:	Joe Grani		
INITIAL CONDITIONS		FINAL CONDITIONS	
Dry Unit Weight (pcf):	97.1	Dry Unit Weight (pcf):	97.1
Moisture Content (%):	25.1	Moisture Content (%):	25.3
Total Unit Weight (pcf):	121.5	Total Unit Weight (pcf):	121.7
B Parameter:	0.98	Area (Ac, Method A) (sq.in.):	6.319

	Effective Stresses			Total Stresses		
Axial Strain (%)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Pore Press. (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Deviator Stress (psf)
0.0	878	878	7762	878	878	0
0.1	1341	706	7934	1514	878	636
0.2	1374	605	8035	1648	878	770
0.3	1436	533	8107	1782	878	904
0.4	1542	504	8136	1916	878	1038
0.4	1602	475	8165	2005	878	1127
0.9	1875	374	8266	2379	878	1501
1.3	2121	360	8280	2639	878	1761
1.8	2304	374	8266	2808	878	1930
2.2	2419	389	8251	2909	878	2031
2.7	2542	432	8208	2988	878	2110
3.1	2604	461	8179	3022	878	2144
3.5	2666	490	8150	3055	878	2177
4.4	2762	518	8122	3122	878	2244
5.3	2848	562	8078	3165	878	2287
6.2	2898	590	8050	3186	878	2308
7.1	2968	619	8021	3227	878	2349
8.0	3016	648	7992	3246	878	2368
8.9	3062	677	7963	3264	878	2386
9.7	3115	691	7949	3302	878	2424
10.6	3180	720	7920	3338	878	2460
11.5	3230	734	7906	3374	878	2496
12.4	3278	749	7891	3408	878	2530
13.3	3340	778	7862	3441	878	2563
14.2	3387	792	7848	3473	878	2595
15.0	3412	806	7834	3484	878	2606
15.9	3437	821	7819	3495	878	2617
16.8	3466	821	7819	3524	878	2646
17.7	3461	806	7834	3533	878	2655
18.6	3473	792	7848	3559	878	2681
19.5	3498	792	7848	3584	878	2706
20.4	3536	806	7834	3608	878	2730

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Failure Criterion = 20.0 % Axial Strain

At Failure

Effective Stresses		Total Stresses	
Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)
3521	801	3599	878

Principle Stress Difference = 2720 psf

CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

Client:	Paul C. Rizzo Associates, Inc.	Sample ID:	B4-2
Project:	Buckeye Lake	Depth Interval:	8'-10'
Project #:	96050030	Compaction (%):	---
Date:	9/27/96	Cell Confining Pressure (psf):	1094.4
Checked:	Joe Grani		
INITIAL CONDITIONS		FINAL CONDITIONS	
Dry Unit Weight (pcf):	95.1	Dry Unit Weight (pcf):	95.1
Moisture Content (%):	26.9	Moisture Content (%):	26.4
Total Unit Weight (pcf):	120.7	Total Unit Weight (pcf):	120.2
B Parameter:	0.98	Area (Ac, Method A) (sq.in.):	6.296

	Effective Stresses			Total Stresses		
Axial Strain (%)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Pore Press. (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Deviator Stress (psf)
0.0	1094	1094	7546	1094	1094	0
0.1	1683	864	7776	1913	1094	819
0.2	1807	763	7877	2138	1094	1044
0.3	1831	677	7963	2249	1094	1155
0.4	1886	619	8021	2361	1094	1267
0.5	1932	576	8064	2450	1094	1356
0.9	2185	432	8208	2847	1094	1753
1.3	2345	288	8352	3151	1094	2057
1.8	2433	230	8410	3297	1094	2203
2.2	2460	202	8438	3353	1094	2259
2.7	2493	202	8438	3386	1094	2292
3.1	2527	202	8438	3420	1094	2326
3.6	2553	216	8424	3431	1094	2337
4.5	2596	216	8424	3474	1094	2380
5.4	2673	230	8410	3537	1094	2443
6.3	2727	245	8395	3577	1094	2483
7.2	2782	259	8381	3617	1094	2523
8.1	2854	274	8366	3675	1094	2581
9.0	2920	302	8338	3712	1094	2618
9.9	2989	317	8323	3767	1094	2673
10.8	3073	346	8294	3822	1094	2728
11.7	3120	360	8280	3854	1094	2760
12.6	3185	374	8266	3905	1094	2811
13.4	3234	374	8266	3954	1094	2860
14.3	3296	389	8251	4002	1094	2908
15.2	3357	403	8237	4048	1094	2954
16.1	3431	432	8208	4093	1094	2999
17.0	3488	446	8194	4136	1094	3042
17.9	3562	461	8179	4196	1094	3102
18.8	3598	475	8165	4217	1094	3123
19.7	3686	490	8150	4291	1094	3197
20.6	3702	504	8136	4292	1094	3198

CTL ENGINEERING INC.

Failure Criterion = 20.0 % Axial Strain

At Failure

Effective Stresses		Total Stresses	
Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)
3691	494	4291	1094

Principle Stress Difference = 3197 psf

CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

Client: Paul C. Rizzo Associates, Inc.		Sample ID:	B4-2
Project: Buckeye Lake		Depth Interval:	8'-10'
Project #: 96050030		Compaction (%):	---
Date: 9/27/96		Cell Confining Pressure (psf):	2188.8
Checked: Joe Grani			
INITIAL CONDITIONS		FINAL CONDITIONS	
Dry Unit Weight (pcf):	97.5	Dry Unit Weight (pcf):	97.5
Moisture Content (%):	26.3	Moisture Content (%):	23.2
Total Unit Weight (pcf):	123.1	Total Unit Weight (pcf):	120.1
B Parameter:	0.96	Area (Ac, Method A) (sq.in.):	6.197

	Effective Stresses			Total Stresses		
Axial Strain (%)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Pore Press. (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Deviator Stress (psf)
0.0	2189	2189	6451	2189	2189	0
0.1	2867	1944	6696	3112	2189	923
0.2	2945	1656	6984	3478	2189	1289
0.3	2986	1469	7171	3706	2189	1517
0.4	3040	1296	7344	3933	2189	1744
0.4	3069	1166	7474	4091	2189	1902
0.9	3273	720	7920	4742	2189	2553
1.3	3538	475	8165	5252	2189	3063
1.8	3733	346	8294	5576	2189	3387
2.2	3929	288	8352	5830	2189	3641
2.7	4114	288	8352	6015	2189	3826
3.1	4281	317	8323	6153	2189	3964
3.6	4424	346	8294	6267	2189	4078
4.4	4678	418	8222	6449	2189	4260
5.3	4928	490	8150	6627	2189	4438
6.2	5073	547	8093	6715	2189	4526
7.1	5301	648	7992	6842	2189	4653
8.0	5471	734	7906	6925	2189	4736
8.9	5622	806	7834	7004	2189	4815
9.8	5757	864	7776	7082	2189	4893
10.6	5904	936	7704	7157	2189	4968
11.5	6014	994	7646	7209	2189	5020
12.4	6142	1051	7589	7280	2189	5091
13.3	6268	1109	7531	7348	2189	5159
14.2	6385	1181	7459	7393	2189	5204
15.1	6486	1238	7402	7436	2189	5247
16.0	6585	1296	7344	7478	2189	5289
16.9	6683	1354	7286	7518	2189	5329
17.7	6763	1397	7243	7555	2189	5366
18.6	6823	1440	7200	7572	2189	5383
19.5	6881	1483	7157	7587	2189	5398
20.4	6939	1526	7114	7601	2189	5412

CTL ENGINEERING INC

Failure Criterion = 20.0 % Axial Strain

At Failure

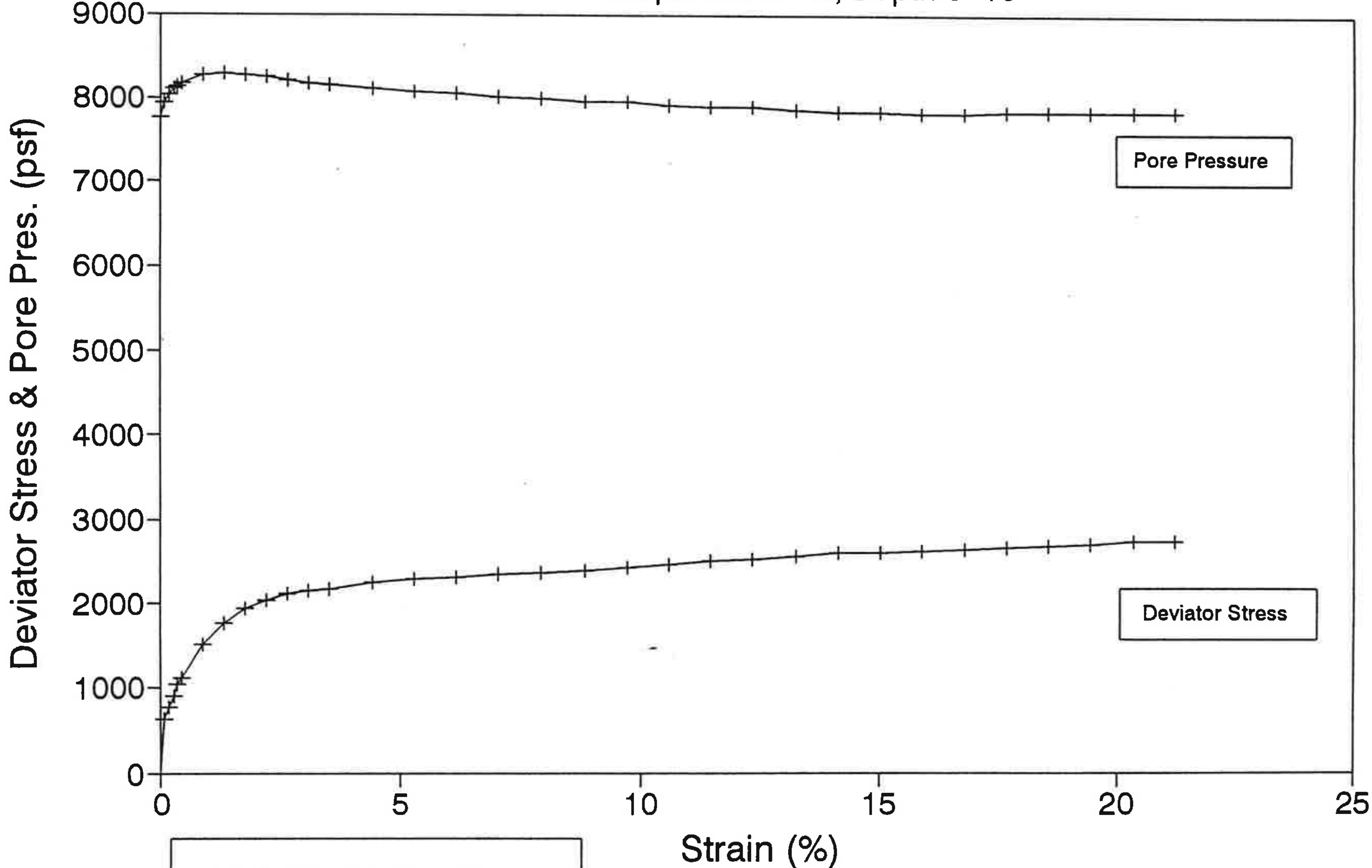
Effective Stresses		Total Stresses	
Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)
6913	1507	7595	2189

Principle Stress Difference = 5406 psf

Deviator Stress, Pore Pres. vs Strain

Confining Pressure=878.4 psf

Sample No. B4-2, Depth 8'-10'



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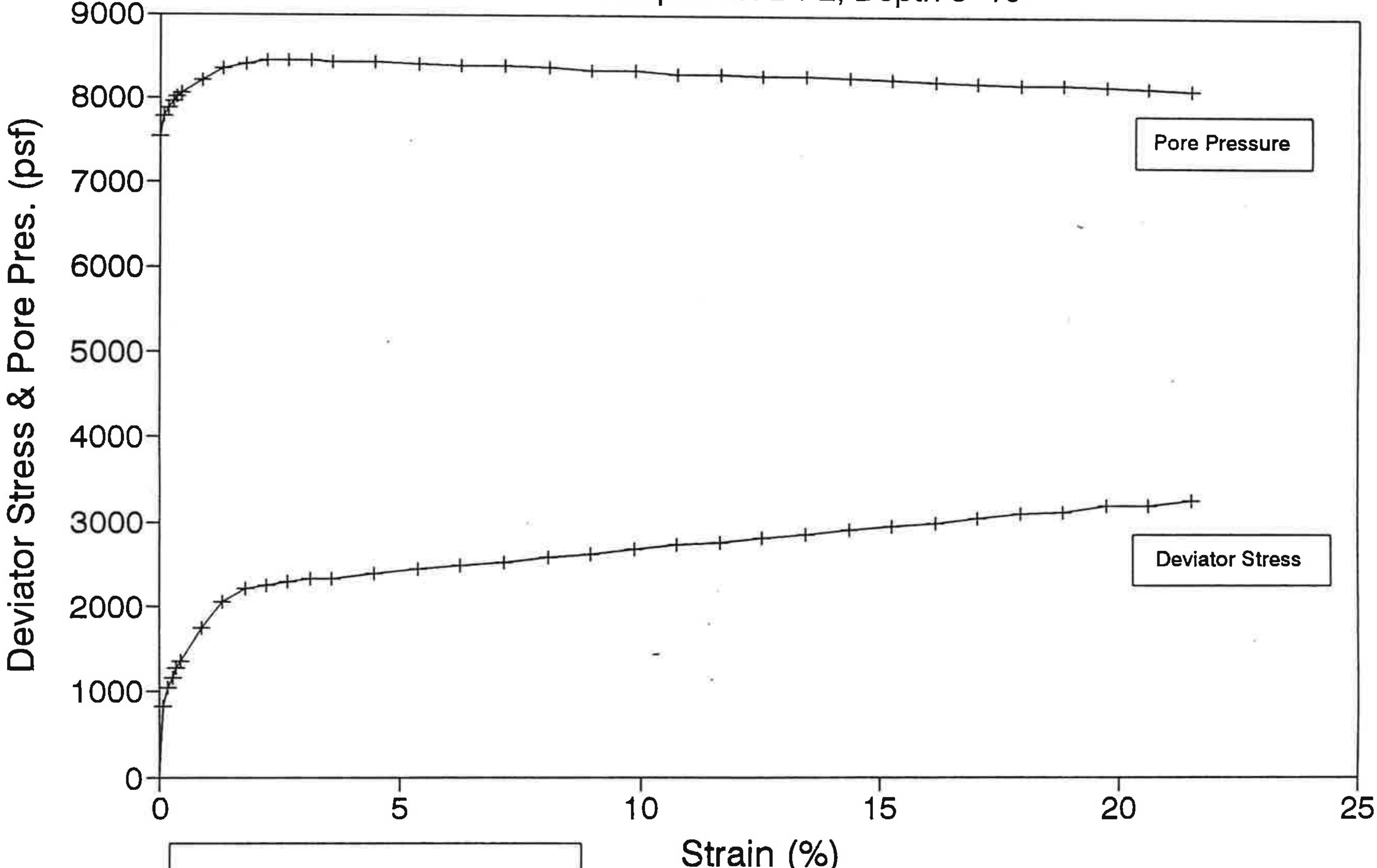
Deviator Stress, Pore Pres. vs Strain

Confining Pressure=1094.4 psf

Sample No. B4-2, Depth 8'-10'



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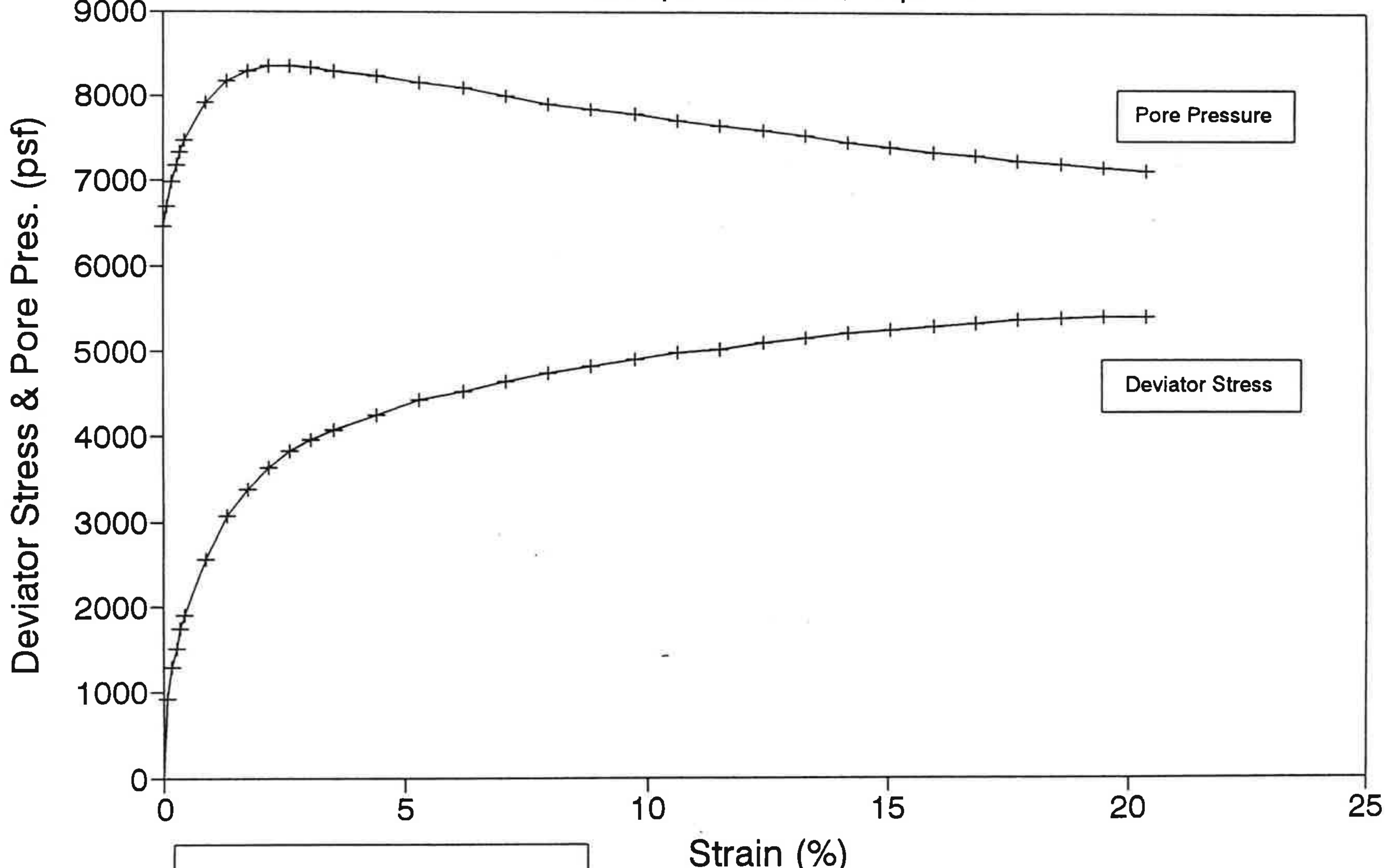
Deviator Stress, Pore Pres. vs Strain

Confining Pressure=2188.8 psf

Sample No. B4-2, Depth 8'-10'



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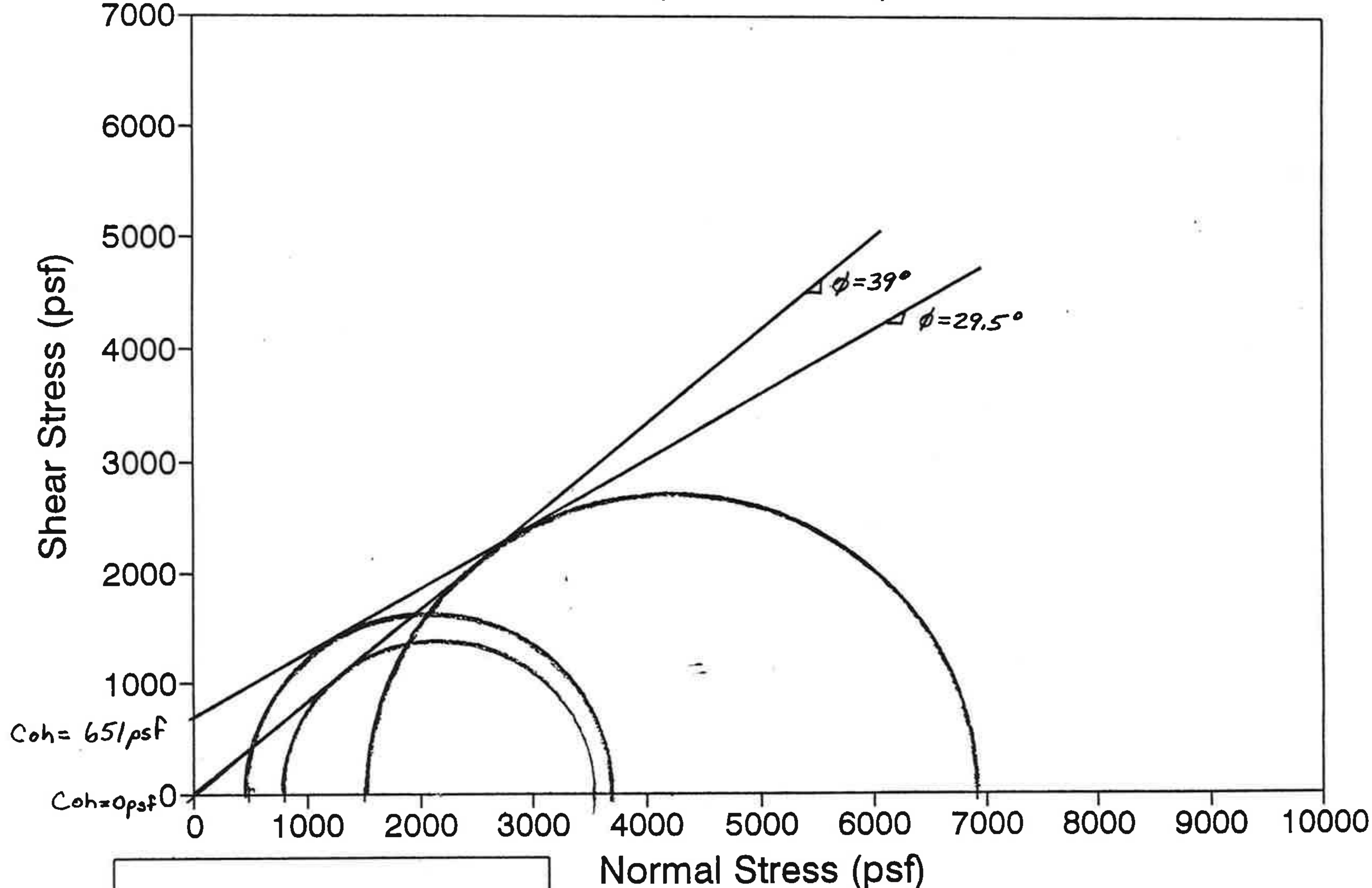
Mohr Circle
Effective Stress

Sample No. B4-2, Depth 8'-10'



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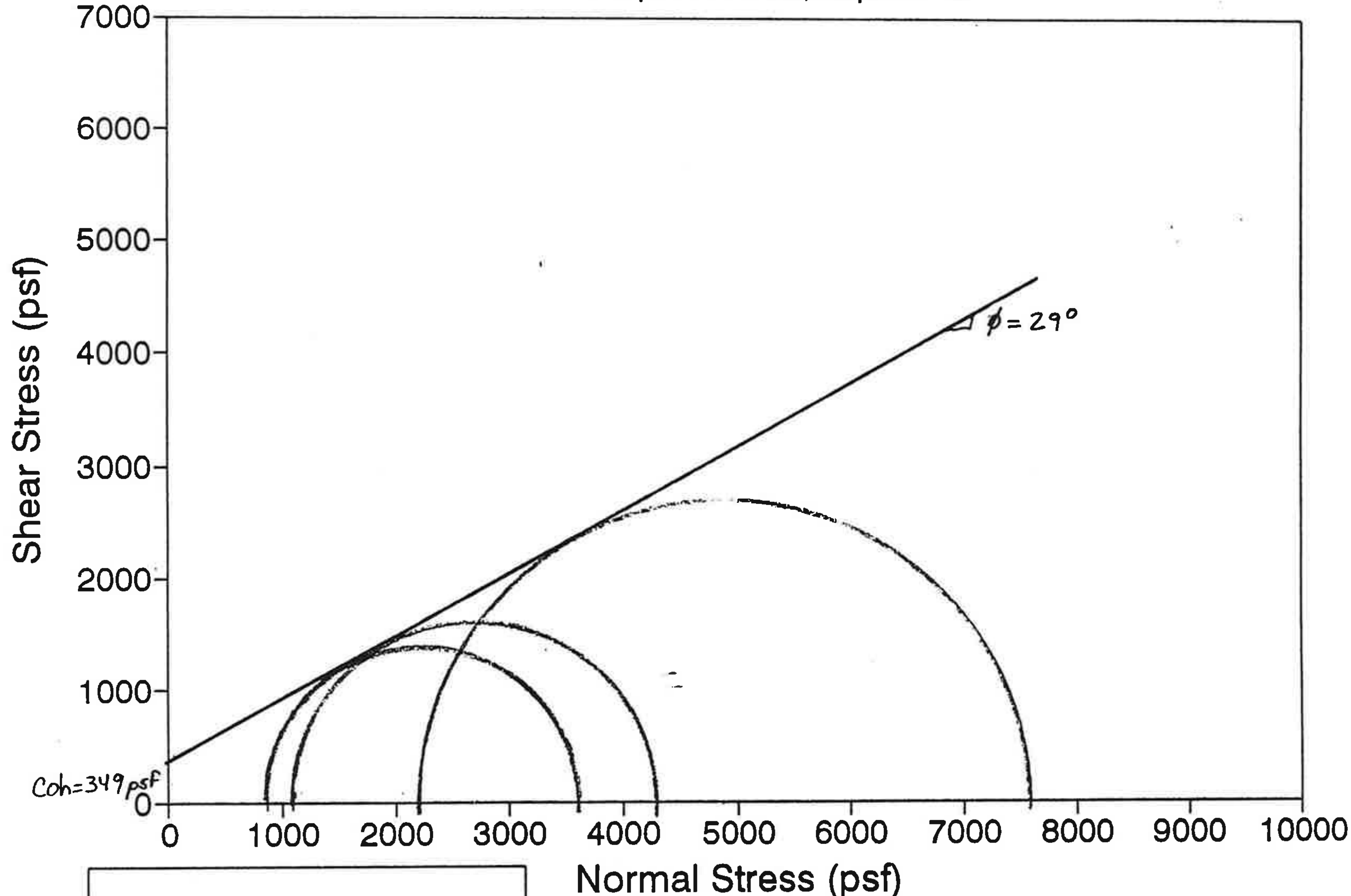
Mohr Circle
Total Stress

Sample No. B4-2, Depth 8'-10'



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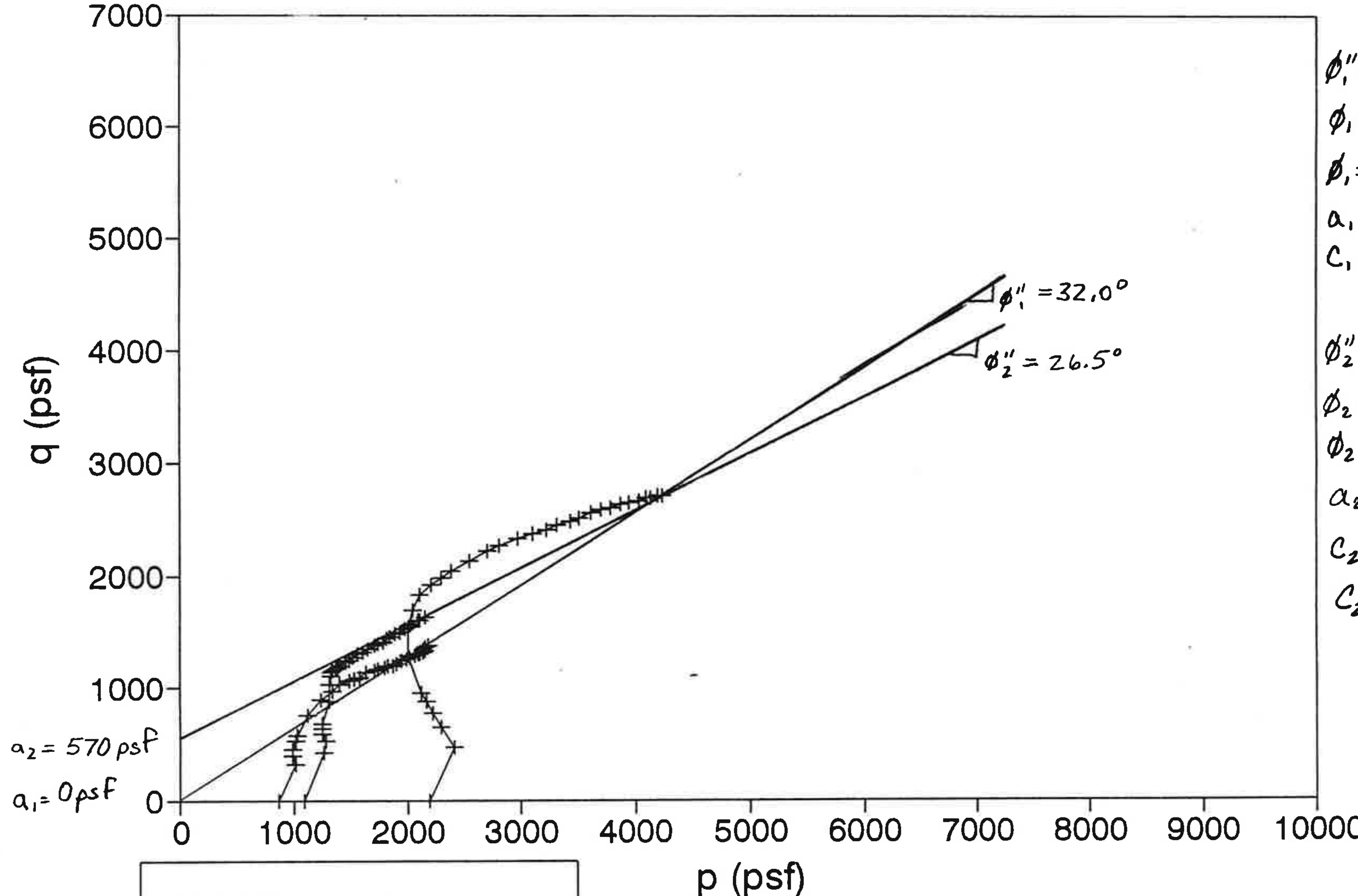
q vs. p
Effective Stress

Sample No. B4-2, Depth 8'-10'



$\phi_1'' = 32.0°$

$\phi_1 = \sin^{-1}(\tan 32.0)$

$\phi_1 = 38.7°$

$a_1 = 0$ psf

$C_1 = 0$ psf

$\phi_2'' = 26.5°$

$\phi_2 = \sin^{-1}(\tan 26.5)$

$\phi_2 = 29.9°$

$a_2 = 570$ psf

$C_2 = a_2 \sec \phi_2$

$C_2 = 658$ psf

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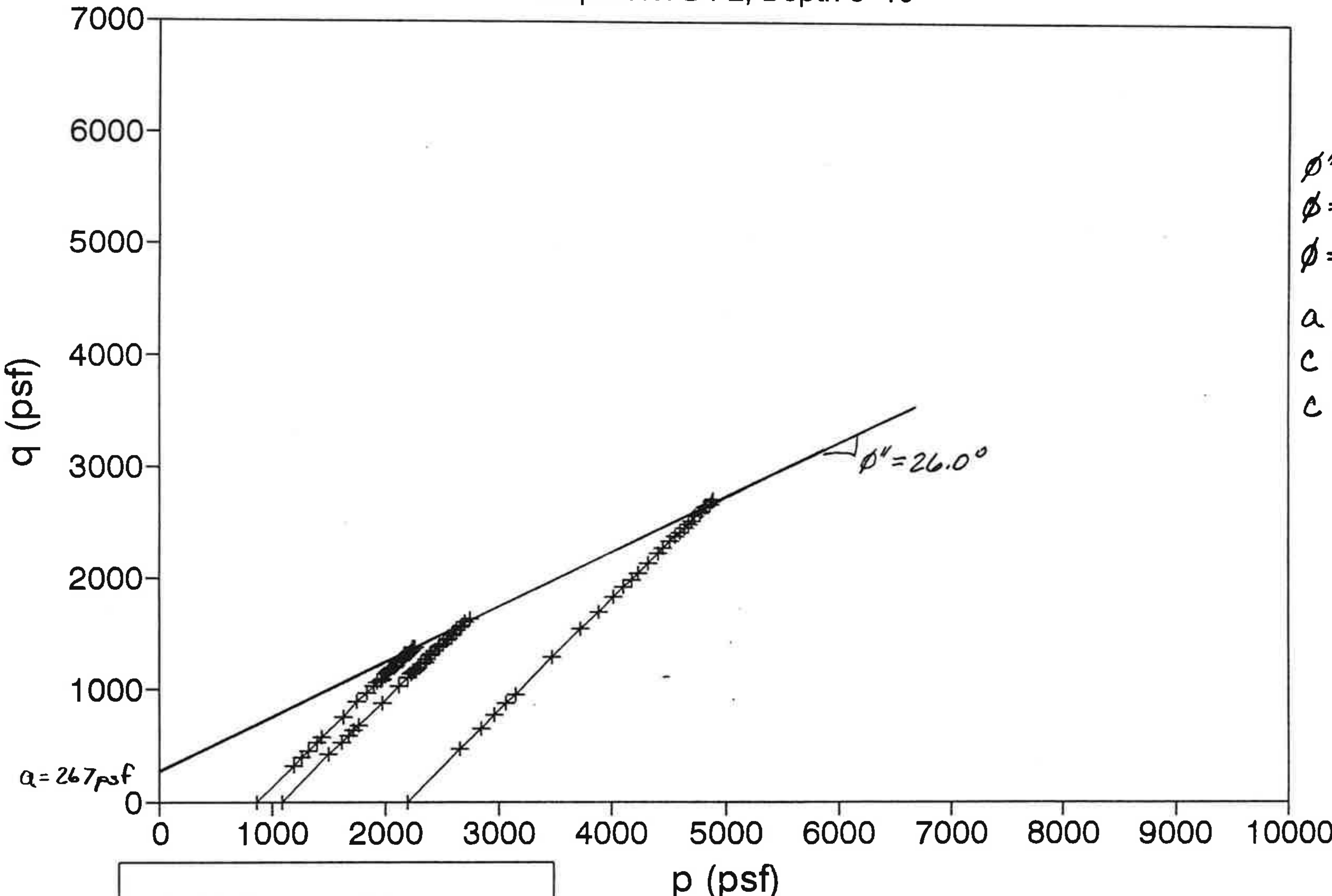
q vs. p
Total Stress

Sample No. B4-2, Depth 8'-10'



$\phi'' = 26.0°$
$\phi = \sin^{-1}(\tan 26.0)$
$\phi = 29.2°$
$a = 267$ psf
$c = a \cdot \sec\phi$
$c = 306$ psf

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CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

Client:	Paul C. Rizzo Associates, Inc.	Sample ID:	B5-3
Project:	Buckeye Lake	Depth Interval:	3.5'-7'
Project #:		Compaction (%):	---
Date:	9/27/96	Cell Confining Pressure (psf):	518.4
Checked:	Joe Grani		
INITIAL CONDITIONS		FINAL CONDITIONS	
Dry Unit Weight (pcf):	96.8	Dry Unit Weight (pcf):	96.8
Moisture Content (%):	26.6	Moisture Content (%):	25.6
Total Unit Weight (pcf):	122.5	Total Unit Weight (pcf):	121.6
B Parameter:	0.98	Area (Ac, Method A) (sq.in.):	6.347

	Effective Stresses			Total Stresses		
Axial Strain (%)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Pore Press. (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Deviator Stress (psf)
0.0	518	518	8122	518	518	0
0.1	950	374	8266	1094	518	576
0.2	997	288	8352	1227	518	709
0.3	1041	245	8395	1315	518	797
0.4	1087	202	8438	1404	518	886
0.4	1124	173	8467	1470	518	952
0.9	1379	101	8539	1797	518	1279
1.3	1697	115	8525	2100	518	1582
1.8	1982	144	8496	2356	518	1838
2.2	2248	245	8395	2522	518	2004
2.7	2456	331	8309	2643	518	2125
3.1	2662	418	8222	2763	518	2245
3.6	2810	490	8150	2839	518	2321
4.4	3089	576	8064	3031	518	2513
5.3	3286	648	7992	3156	518	2638
6.2	3479	720	7920	3277	518	2759
7.1	3663	806	7834	3375	518	2857
8.0	3817	864	7776	3471	518	2953
8.9	3968	922	7718	3565	518	3047
9.8	4102	965	7675	3656	518	3138
10.7	4249	1022	7618	3745	518	3227
11.6	4358	1066	7574	3811	518	3293
12.4	4466	1109	7531	3876	518	3358
13.3	4573	1152	7488	3939	518	3421
14.2	4676	1195	7445	3999	518	3481
15.1	4764	1224	7416	4058	518	3540
16.0	4864	1267	7373	4115	518	3597
16.9	4929	1296	7344	4151	518	3633
17.8	4991	1325	7315	4185	518	3667
18.7	5071	1354	7286	4236	518	3718
19.6	5132	1382	7258	4268	518	3750
20.4	5172	1411	7229	4279	518	3761

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Failure Criterion = 20.0 % Axial Strain

At Failure

Effective Stresses		Total Stresses	
Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)
5152	1397	4274	518

Principle Stress Difference = 3755 psf

CTL ENGINEERING INC

CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

Client:	Paul C. Rizzo Associates, Inc.	Sample ID:	B5-3
Project:	Buckeye Lake	Depth Interval:	3.5'-7'
Project #:		Compaction (%):	---
Date:	9/27/96	Cell Confining Pressure (psf):	648
Checked:	Joe Grani		
INITIAL CONDITIONS		FINAL CONDITIONS	
Dry Unit Weight (pcf):	97.2	Dry Unit Weight (pcf):	97.2
Moisture Content (%):	26.8	Moisture Content (%):	25.6
Total Unit Weight (pcf):	123.2	Total Unit Weight (pcf):	122.1
B Parameter:	0.98	Area (Ac, Method A) (sq.in.):	6.351

	Effective Stresses			Total Stresses		
Axial Strain (%)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Pore Press. (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Deviator Stress (psf)
0.0	648	648	7992	648	648	0
0.1	1095	475	8165	1268	648	620
0.2	1171	418	8222	1401	648	753
0.3	1230	389	8251	1489	648	841
0.4	1267	360	8280	1555	648	907
0.4	1319	346	8294	1621	648	973
0.9	1609	331	8309	1926	648	1278
1.3	1883	346	8294	2185	648	1537
1.8	2109	360	8280	2397	648	1749
2.2	2210	360	8280	2498	648	1850
2.6	2455	374	8266	2729	648	2081
3.1	2612	389	8251	2871	648	2223
3.5	2745	403	8237	2990	648	2342
4.4	2995	461	8179	3182	648	2534
5.3	3226	504	8136	3370	648	2722
6.1	3426	562	8078	3512	648	2864
7.0	3638	634	8006	3652	648	3004
7.9	3825	706	7934	3767	648	3119
8.8	3989	778	7862	3859	648	3211
9.6	4151	850	7790	3949	648	3301
10.5	4276	907	7733	4017	648	3369
11.4	4400	965	7675	4083	648	3435
12.3	4521	1022	7618	4147	648	3499
13.2	4621	1080	7560	4189	648	3541
14.0	4740	1138	7502	4250	648	3602
14.9	4836	1195	7445	4289	648	3641
15.8	4916	1238	7402	4326	648	3678
16.7	5015	1282	7358	4381	648	3733
17.5	5093	1325	7315	4416	648	3768
18.4	5154	1354	7286	4448	648	3800
19.3	5229	1397	7243	4480	648	3832
20.2	5301	1440	7200	4509	648	3861

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Failure Criterion = 20.0 % Axial Strain

At Failure

Effective Stresses		Total Stresses	
Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)
5288	1432	4504	648

Principle Stress Difference = 3856 psf

CTL ENGINEERING INC

CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

Client:	Paul C. Rizzo Associates, Inc.	Sample ID:	B5-3
Project:	Buckeye Lake	Depth Interval:	3.5'-7'
Project #:	96050030	Compaction (%):	---
Date:	9/27/96	Cell Confining Pressure (psf):	1296
Checked:	Joe Grani		
INITIAL CONDITIONS		FINAL CONDITIONS	
Dry Unit Weight (pcf):	99.2	Dry Unit Weight (pcf):	99.2
Moisture Content (%):	25.8	Moisture Content (%):	24.6
Total Unit Weight (pcf):	124.8	Total Unit Weight (pcf):	123.6
B Parameter:	0.96	Area (Ac, Method A) (sq.in.):	6.311

	Effective Stresses			Total Stresses		
Axial Strain (%)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Pore Press. (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Deviator Stress (psf)
0.0	1296	1296	7344	1296	1296	0
0.1	1784	936	7704	2144	1296	848
0.2	1847	821	7819	2322	1296	1026
0.3	1880	720	7920	2456	1296	1160
0.4	1941	648	7992	2589	1296	1293
0.4	1980	576	8064	2700	1296	1404
0.9	2276	389	8251	3183	1296	1887
1.3	2697	331	8309	3662	1296	2366
1.8	3149	331	8309	4114	1296	2818
2.2	3633	389	8251	4540	1296	3244
2.7	4054	475	8165	4875	1296	3579
3.1	4429	562	8078	5163	1296	3867
3.6	4750	662	7978	5384	1296	4088
4.4	5221	806	7834	5711	1296	4415
5.3	5706	950	7690	6052	1296	4756
6.2	6023	1080	7560	6239	1296	4943
7.1	6320	1195	7445	6421	1296	5125
8.0	6558	1296	7344	6558	1296	5262
8.9	6787	1411	7229	6672	1296	5376
9.8	6997	1512	7128	6781	1296	5485
10.7	7169	1598	7042	6867	1296	5571
11.6	7374	1699	6941	6971	1296	5675
12.4	7506	1771	6869	7031	1296	5735
13.3	7652	1858	6782	7090	1296	5794
14.2	7814	1944	6696	7166	1296	5870
15.1	7954	2030	6610	7220	1296	5924
16.0	8087	2131	6509	7252	1296	5956
16.9	8188	2203	6437	7281	1296	5985
17.8	8304	2290	6350	7310	1296	6014
18.7	8412	2390	6250	7318	1296	6022
19.6	8505	2477	6163	7324	1296	6028
20.4	8597	2563	6077	7330	1296	6034

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Failure Criterion = 20.0 % Axial Strain

At Failure

Effective Stresses		Total Stresses	
Major Princ. Stress (psf)	Minor Princ. Stress (psf)	Major Princ. Stress (psf)	Minor Princ. Stress (psf)
8552	2521	7327	1296

Principle Stress Difference = 6031 psf

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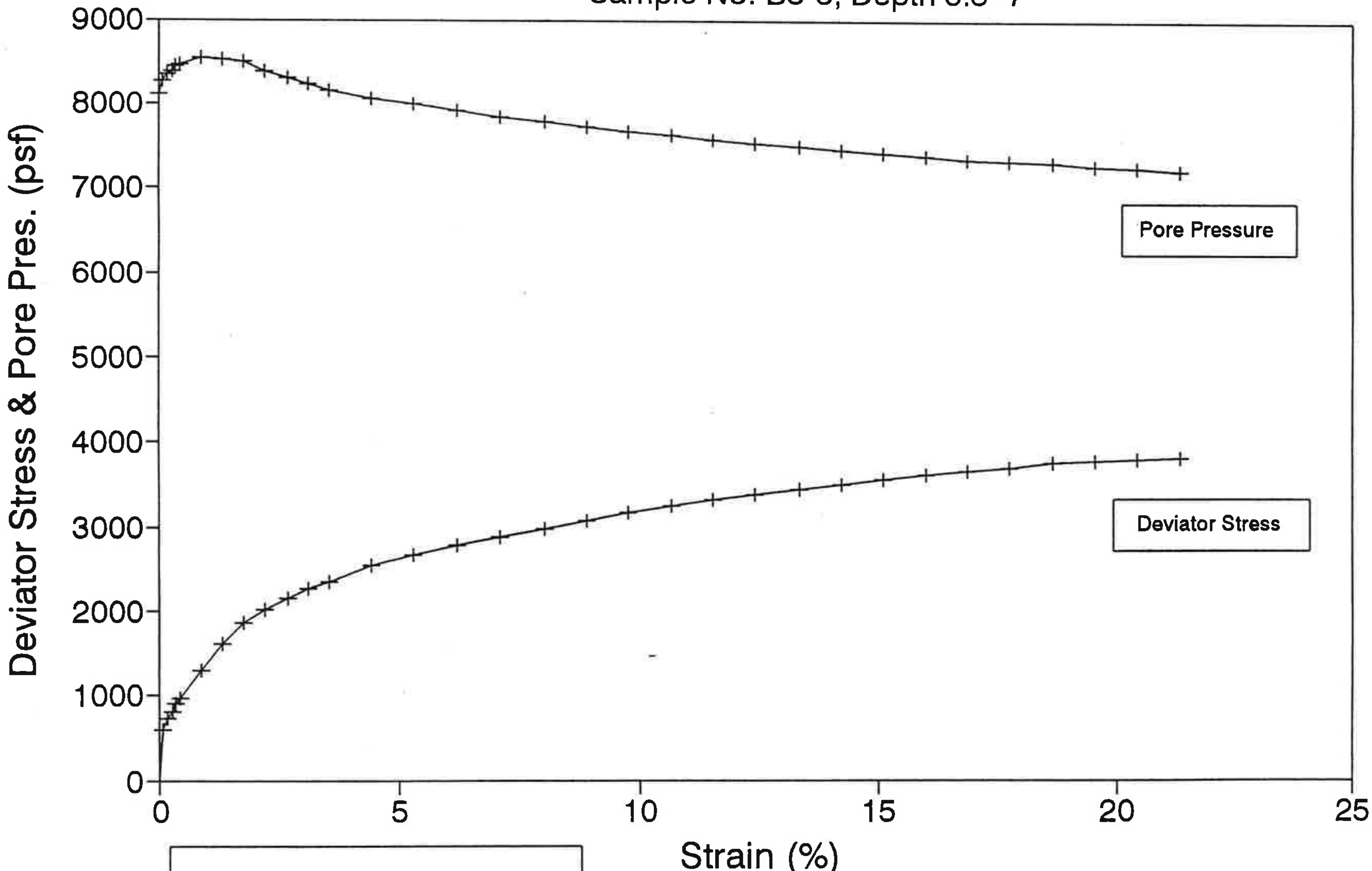
Deviator Stress, Pore Pres. vs Strain

Confining Pressure=518.4 psf

Sample No. B5-3, Depth 3.5'-7'



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Buckeye Lake State Park
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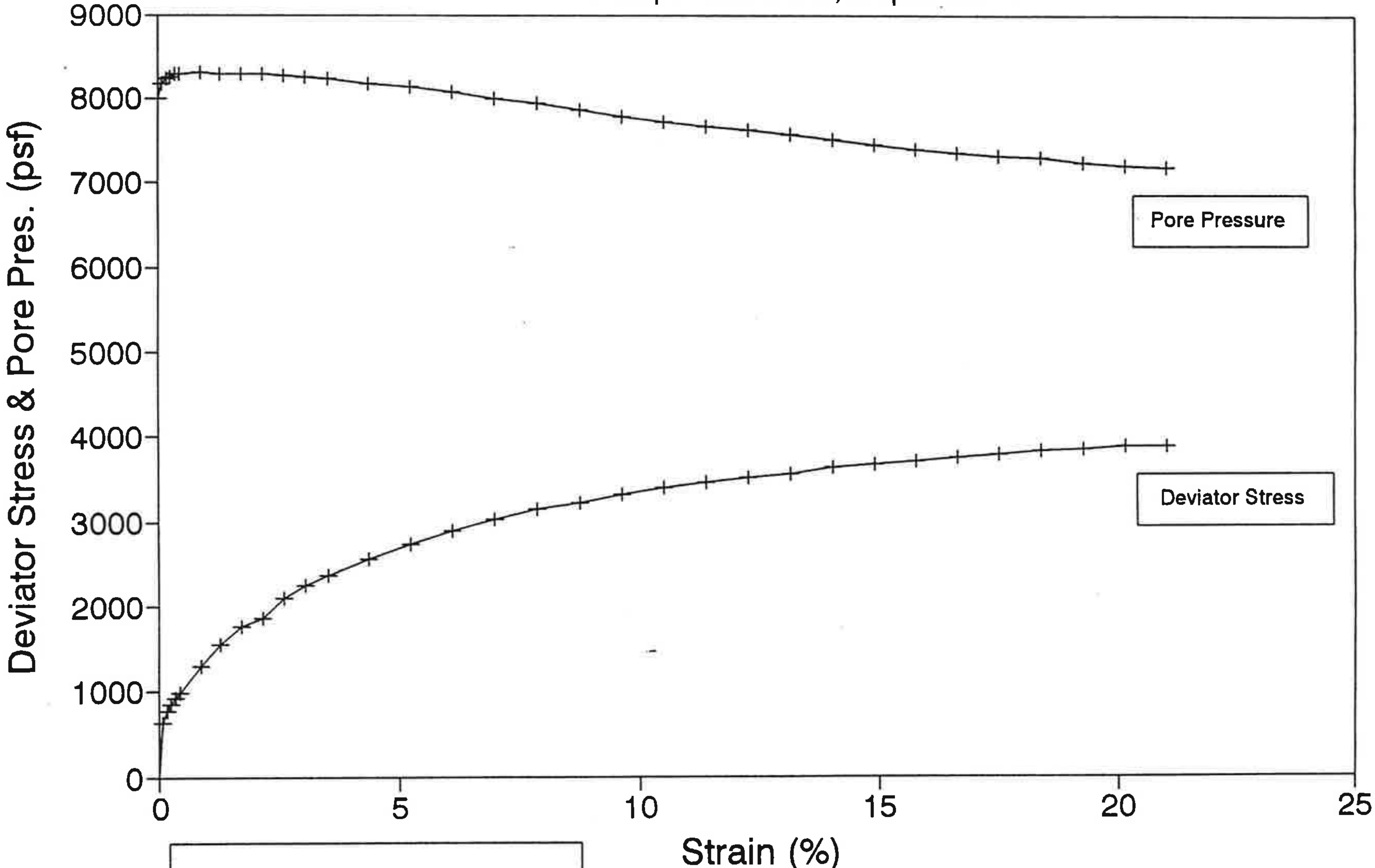
Deviator Stress, Pore Pres. vs Strain
Confining Pressure=648 psf
Sample No. B5-3, Depth 3.5'-7'



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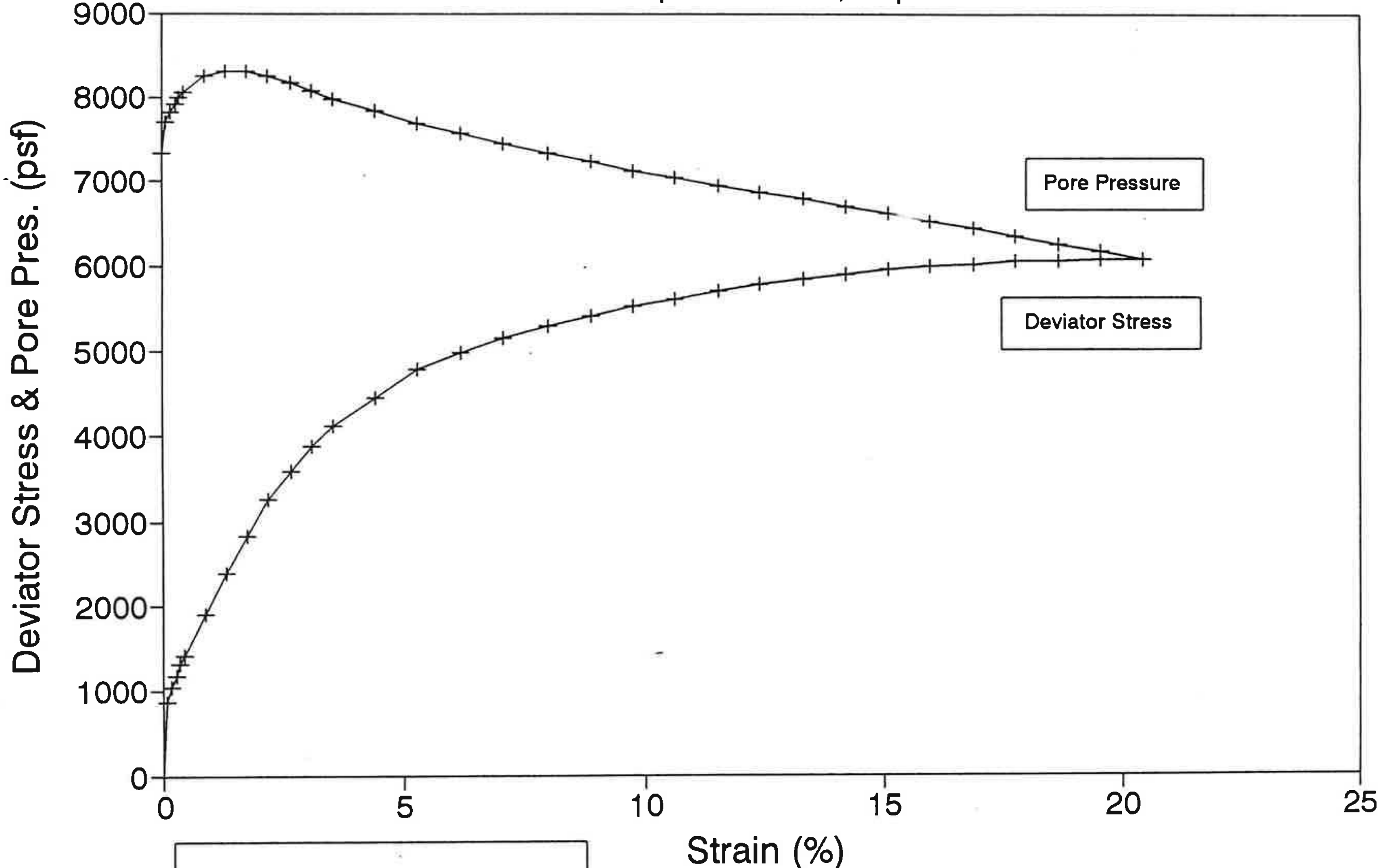
Deviator Stress, Pore Pres. vs Strain

Confining Pressure=1296 psf

Sample No. B5-3, Depth 3.5'-7'



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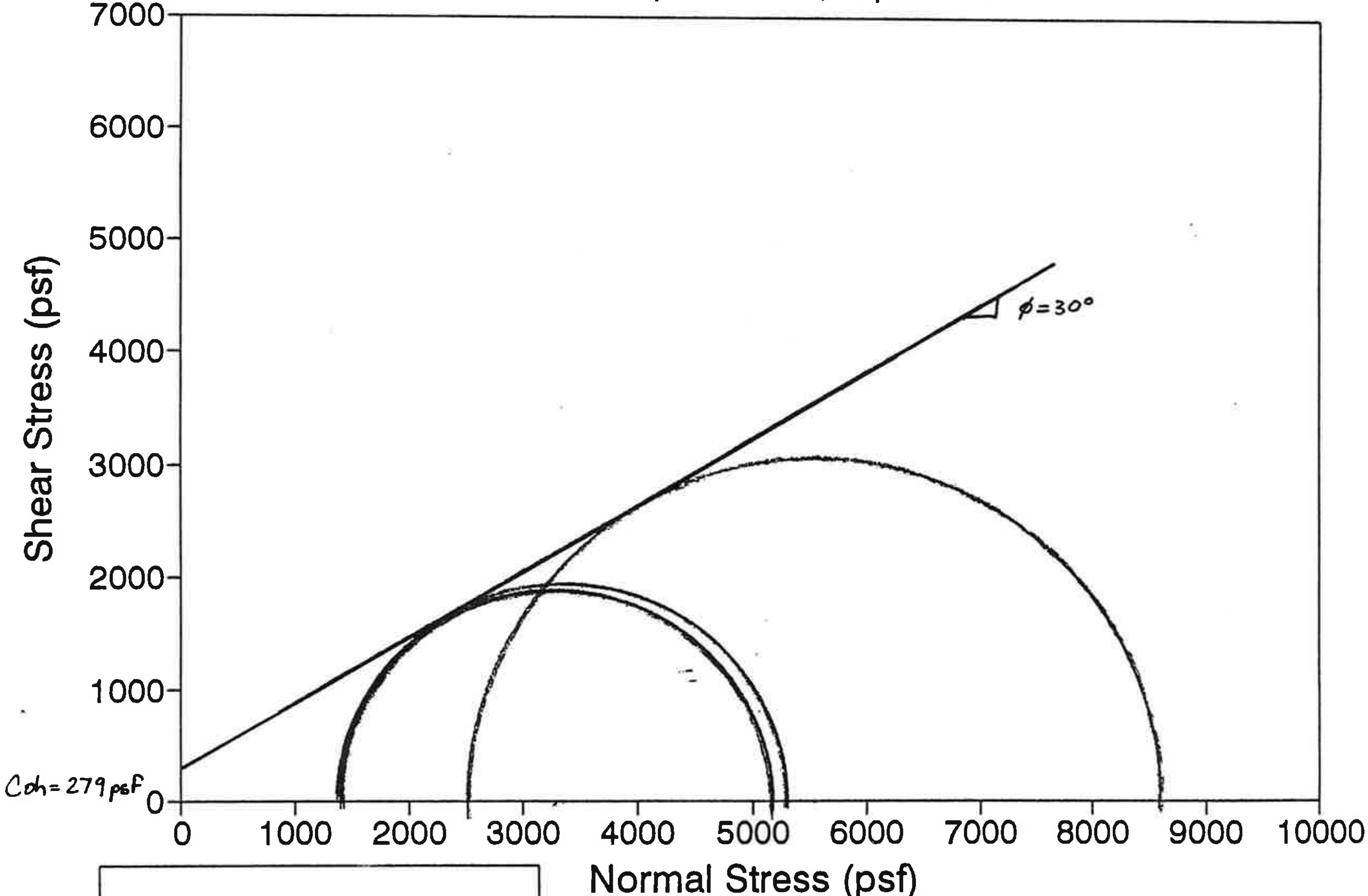
Mohr Circle
Effective Stress

Sample No. B5-3, Depth 3.5'-7'



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Buckeye Lake State Park
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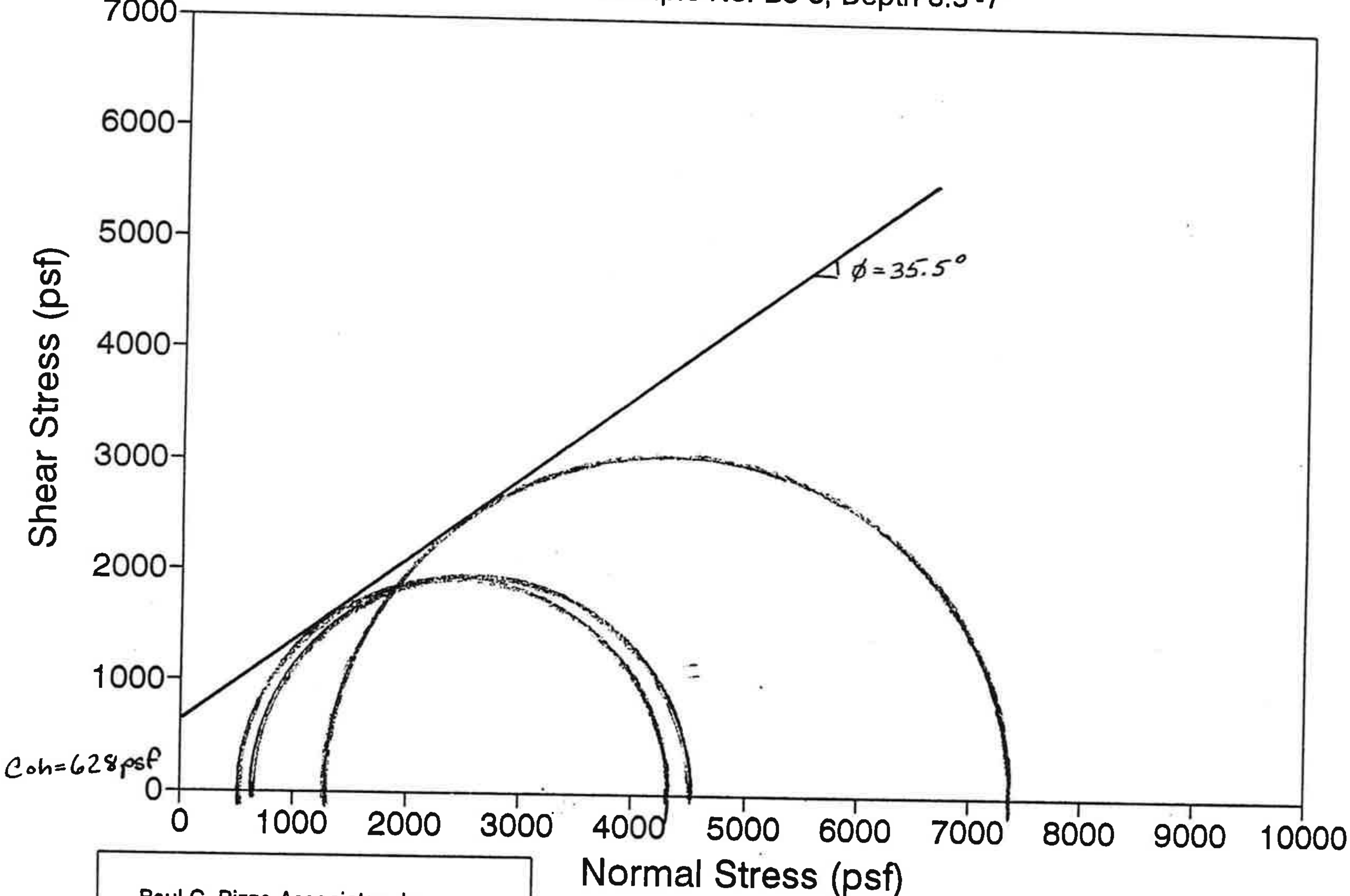
Mohr Circle
Total Stress

Sample No. B5-3, Depth 3.5'-7'



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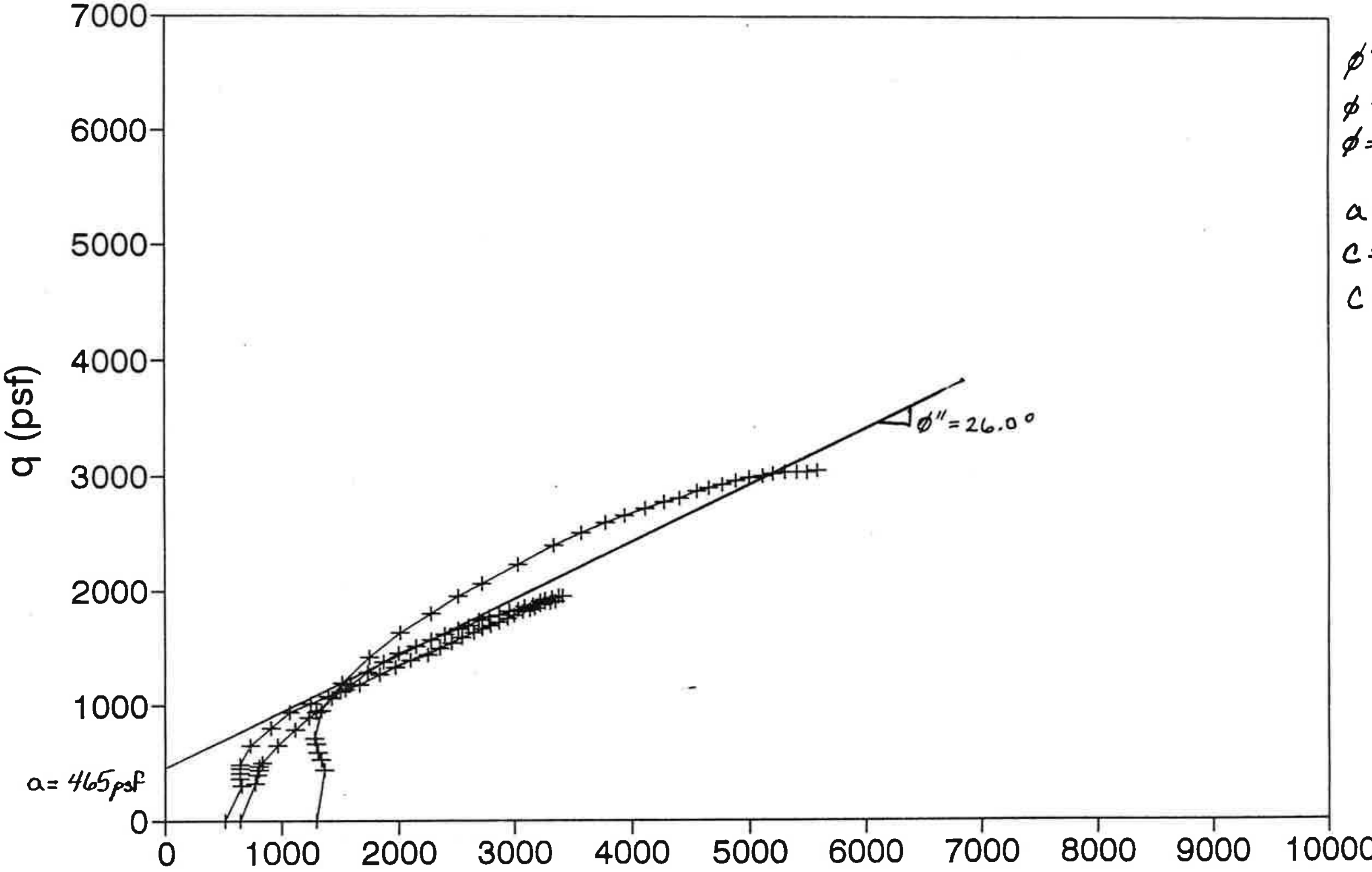
q vs. p
Effective Stress

Sample No. B5-3, Depth 3.5'-7.0'



$\phi'' = 26.0°$
$\phi = \sin^{-1}(\tan 26.0)$
$\phi = 29.2°$

$a = 465$ psf
$c = a \cdot \sec \phi$
$c = 533$ psf

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Buckeye Lake State Park
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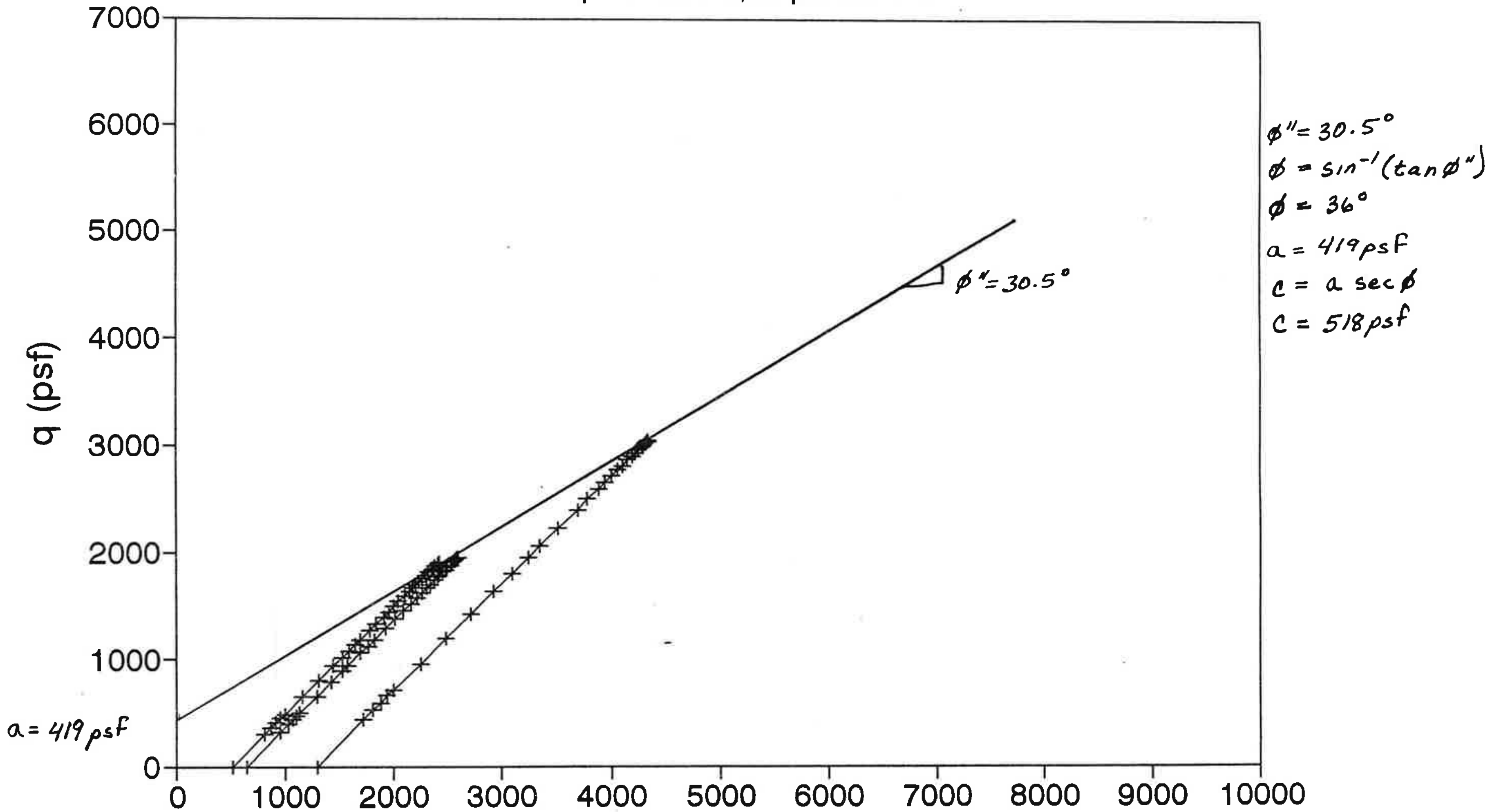
q vs. p
Total Stress

Sample No. B5-3, Depth 3.5'-7.0'



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